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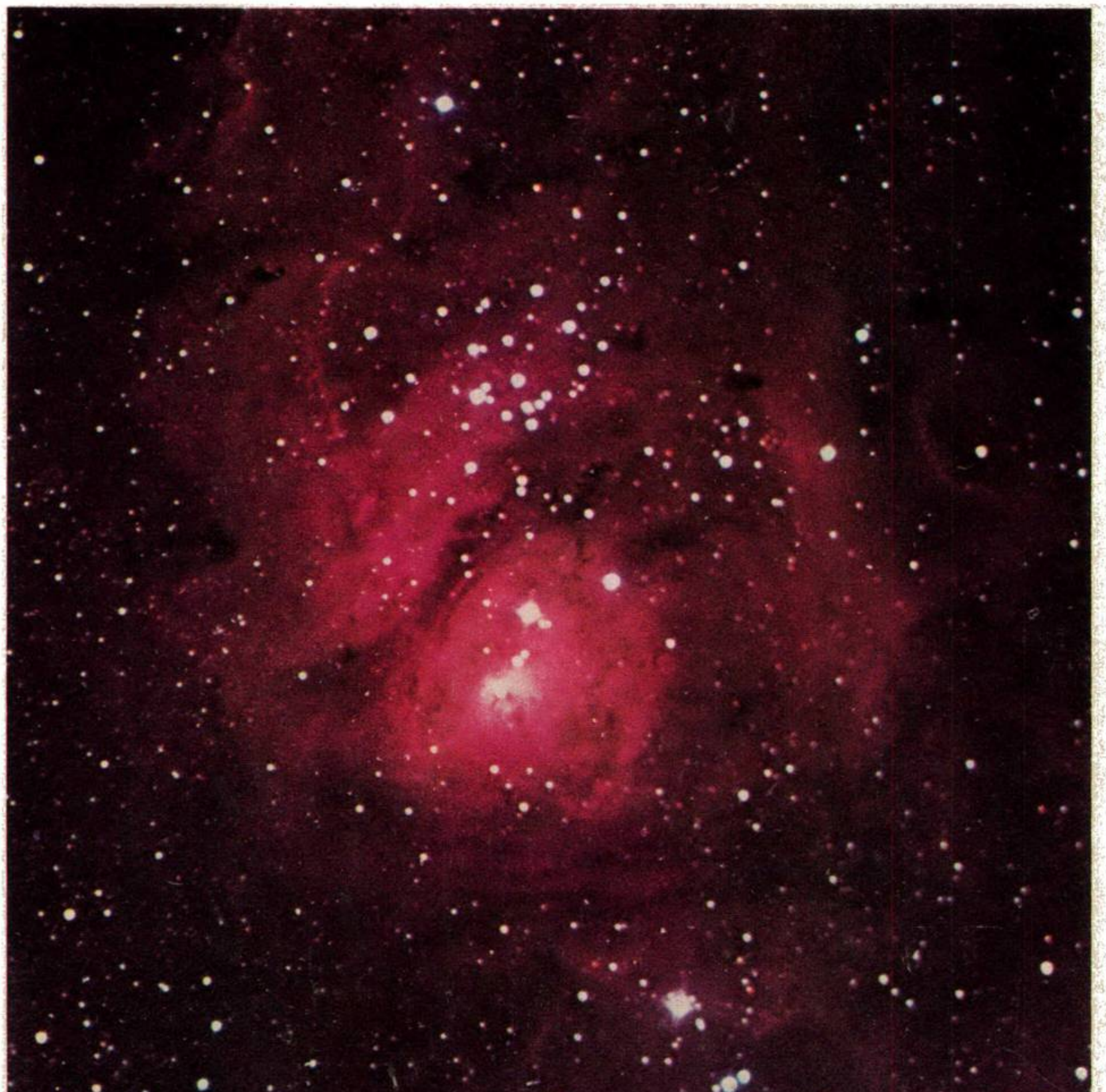

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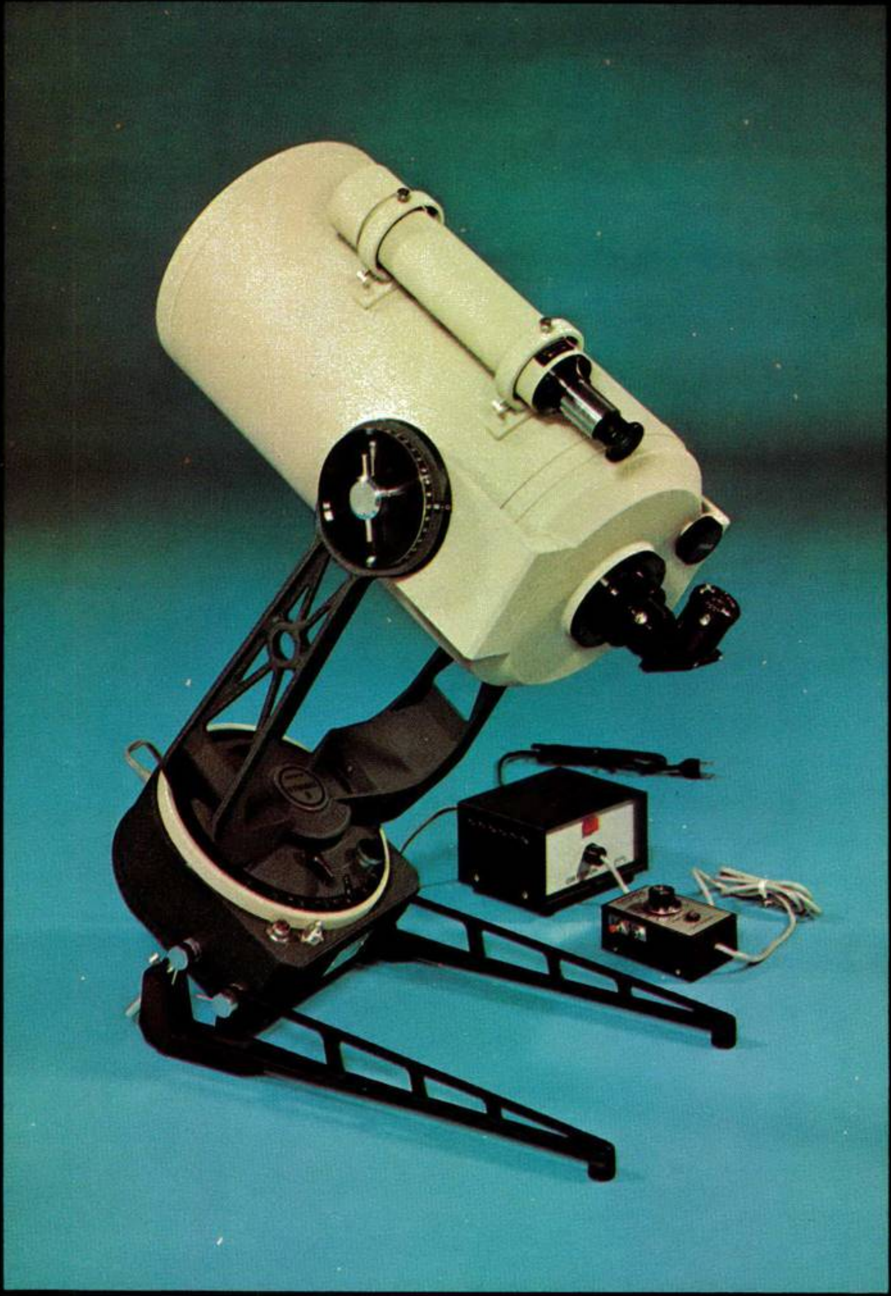

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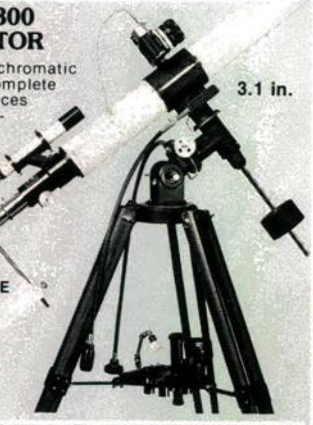

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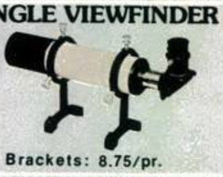

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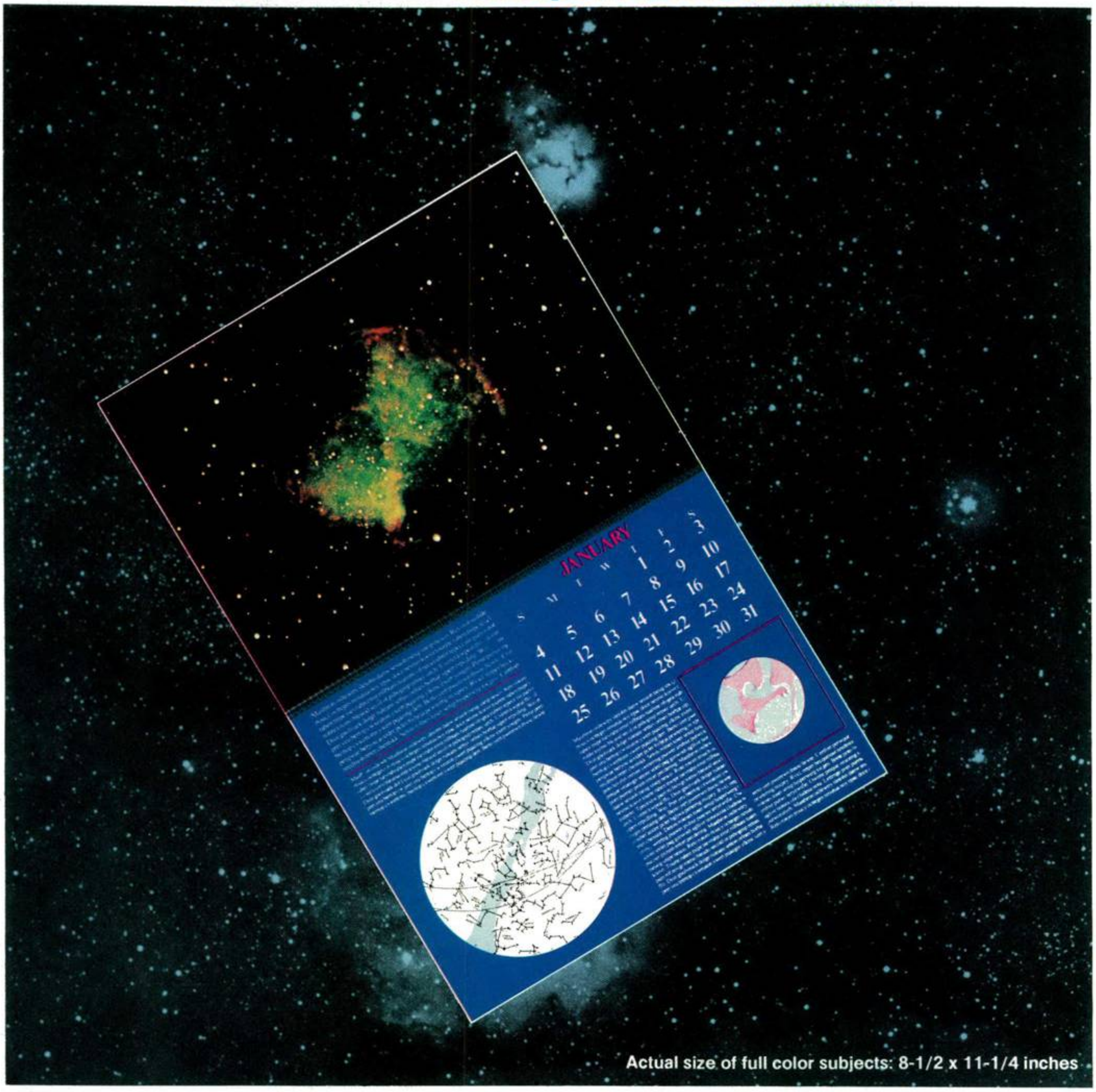

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March 1976 Vol. 4, No. 3

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COVER

The Lagoon nebula is a typical stellar birthplace: a huge cloud of gas and dust in the process of condensing into thousands of new stars. Such an object is frequently a strong source of infrared radiation. Immediately after formation, a young star is often surrounded by a swirling shell of leftover, uncondensed material. This dust envelope may absorb much of the star's energy output, but the star's high temperature can heat the dust which reradiates this heat at infrared wavelengths. The dark knots in the Lagoon nebula may be concentrations of dust in a stage just prior to actual star birth. Photograph by Orien A. Ernest.

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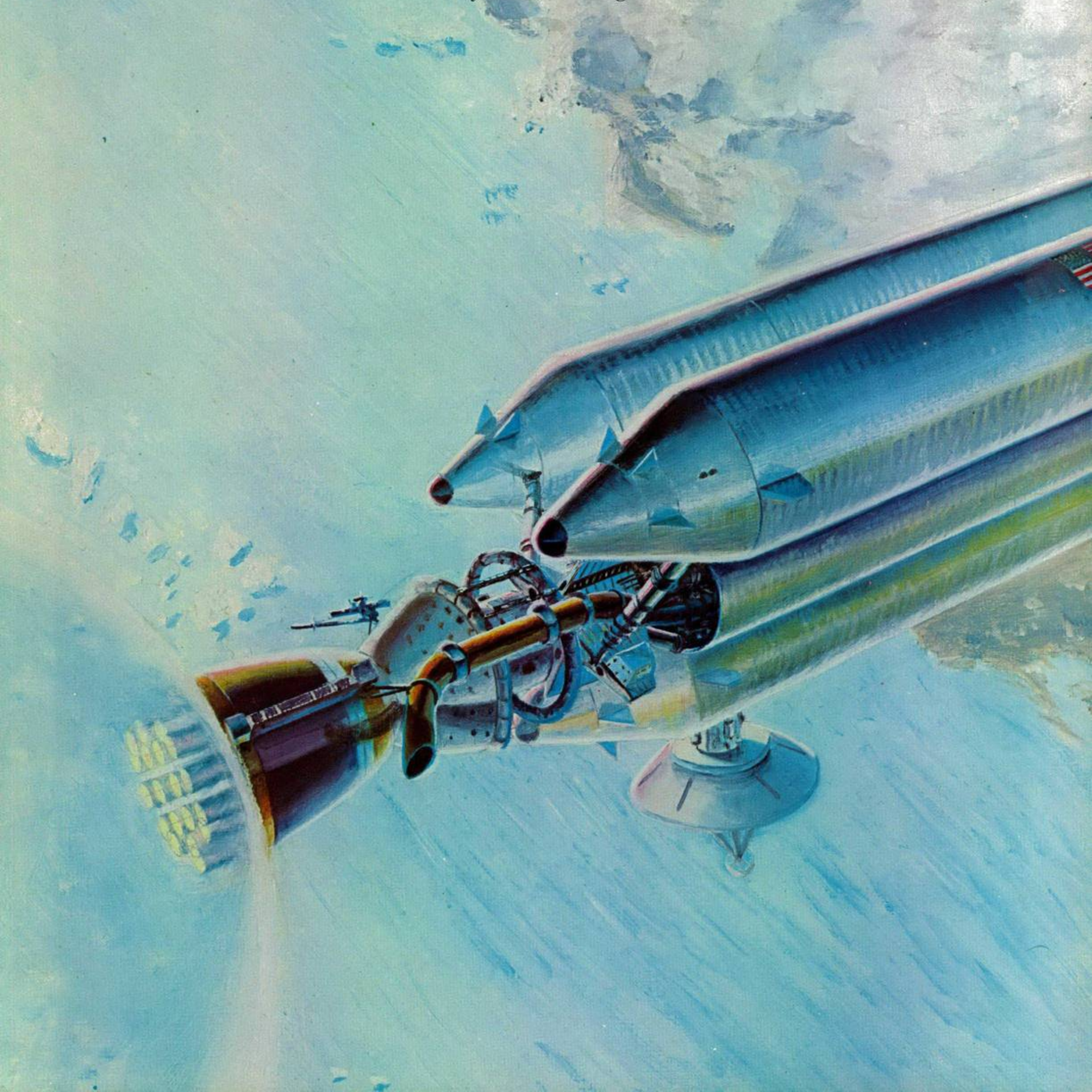
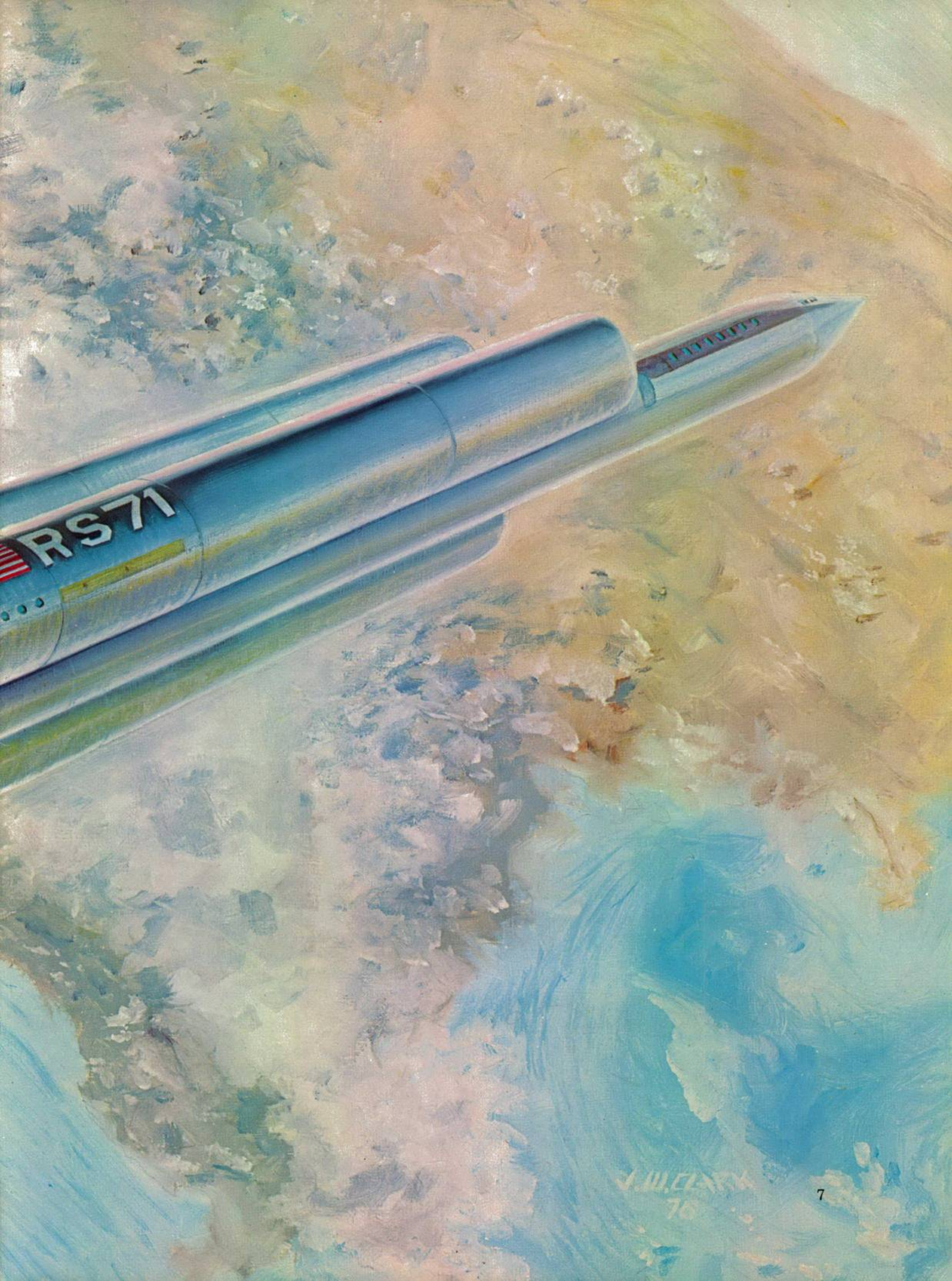
BEYOND SPACE SHUTTLE

by James E. Oberg

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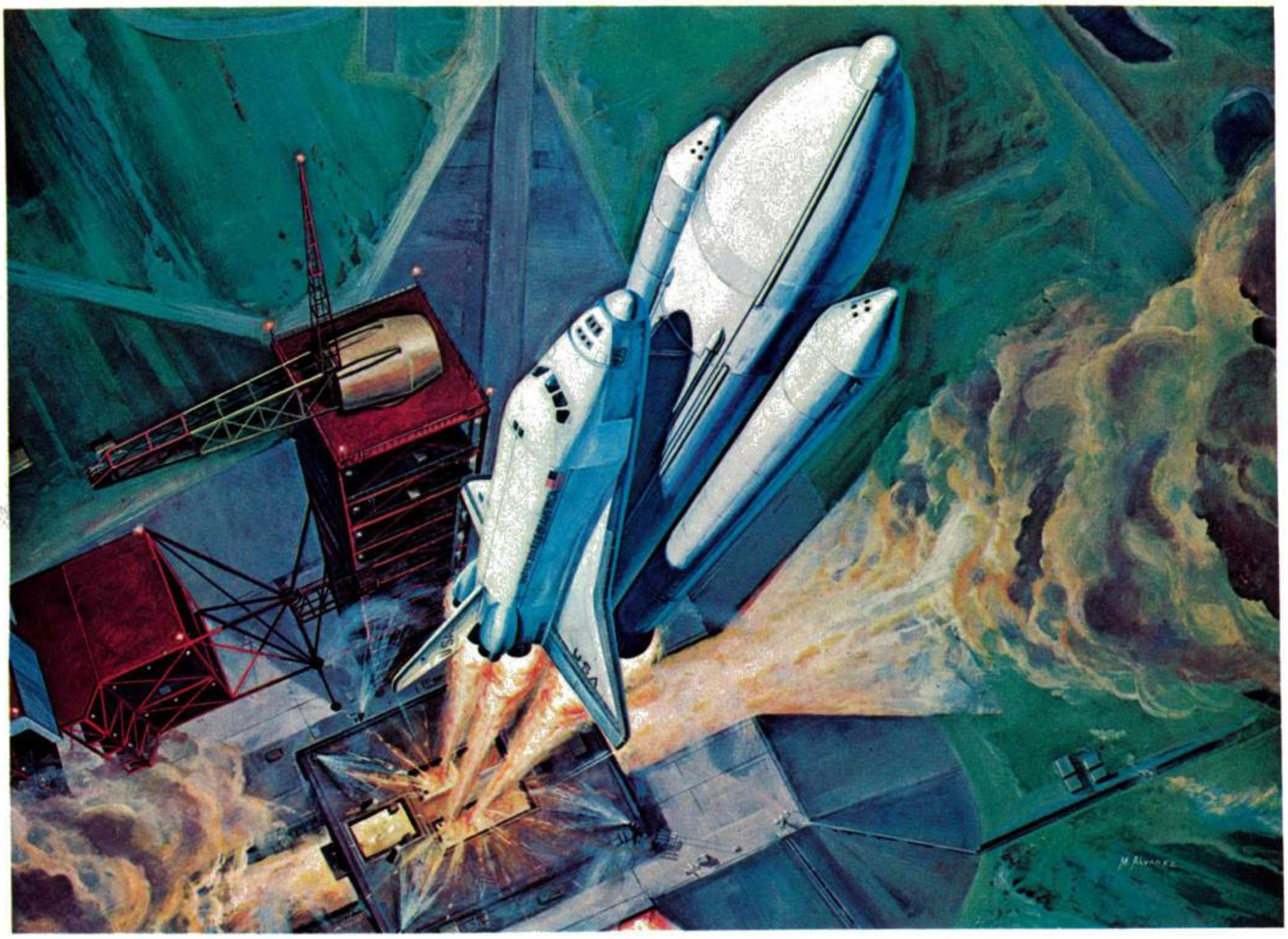


The history of exploration and discovery has been a history of transportation and new transport vehicles. As men developed new technologies for moving himself and his property around the world, his mental and physical horizons expanded together. The greatest human myths have been those of epic voyages: Each new craft — chariot, horse, sailboat, hot air balloon, rocket — tempted men to ride as far as possible. Even the "dream" vehicles — from flying carpets to flying saucers — have broadened the mind's horizons.

All sciences have gained from this exploration, from new discoveries of continents, species, cultures, minerals and ideas. Old theories of the universe were put to the test, making the truth clearer. For example, the theory of evolution and the subsequent convulsion in the biological sciences had their origin on the voyage of the H.M.S. "Beagle".

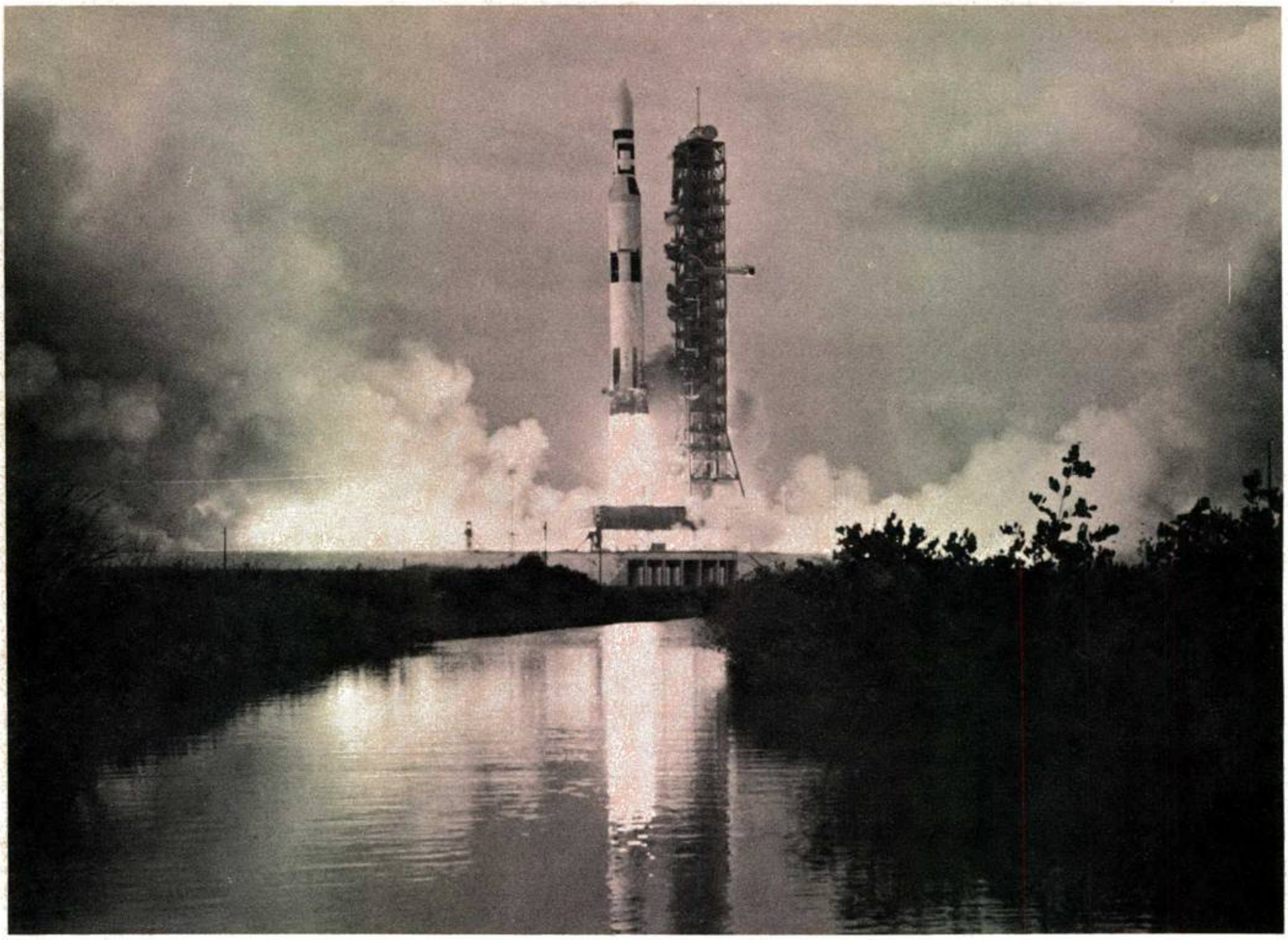
Parallel with the development of new transportation technologies has been the reduction of transportation cost. Legend relates that the first voyage to America cost a queen's treasury; five centuries later, any man can make the trip himself for less than a month's salary. The first trip to the moon cost more than most countries' national annual budgets; the centennial anniversary of that trip will probably see a re-enactment of the flight financed by an amateur rocketry club. The important point is that the mere ability to reach a destination is not enough; those who would benefit from the trip should also be able to afford it.

So it has been with space transportation systems. The first satellites and moon shots were launched without consideration of the costs involved. As space technology improved and new goals came within reach, the number of potential projects exceeded the budgets allocated for space exploration. Brutal judgments of cost effectiveness and probable

A space shuttle of the 1980s (above) blasts off from an old Saturn 5 launch pad at Cape Canaveral. A modified "Orbiter" holds the cargo and crew, and will return to Earth after completing its mission. Attached to its underside is a large external tank containing propellant for the spaceplane's engines. Two solid fuel rocket boosters, assisting in launch, will drop off when empty and descend by parachute, leaving the tank the only nonreusable part of the system. Like the obsolete Saturn F-1 engines (opposite) that launched the moon flights, the shuttle is already headed for the museum — even before it has flown — as technology continues to improve. Above: NASA artwork. Opposite: NASA photograph.

Caption for pages 6 & 7

By the end of this century, spacecraft such as the one portrayed here may become reality. Power is transmitted to the ship from Earth by invisible microwave beams and gathered by the energy-collecting antenna on the vehicle's side. The high energy beam provides thrust while the ship is still in Earth orbit, sending it on a path to the moon. This is only one of many suggested alternatives in the search for more economical space transportation. Artwork by John W. Clark.



gain versus investment had to be made. Many projects were eliminated for others judged more worthwhile; the passage of years gives a hindsight not available at the time. It was soon clear that the cost of space transportation had to come down. Only then would the threshold be crossed and the full potentials of the new environment realized.

One of the major expenses of any space mission is the fiery launching that uses up the first 10 minutes. A large rocket that costs more than a jumbo jet is used only once, and a half hour after the spectacular televised liftoff, a new pile of metal scraps lies at the bottom of the ocean.

As wasteful as this may seem, it was in fact the least expensive way to get into space during the 1960s. For years, engineers had been studying possible methods of booster rocket recovery for reuse. The addition of parachutes, location beacons, flotation collars and strengthened structural elements were all suggested and examined. But such additional weight would significantly reduce the already marginal payload performance of the booster, perhaps resulting in a booster that could be recovered but did not have any extra power left over to orbit a satellite.

While studying mass produced booster rockets with minimal guidance and prelaunch systems, and relying on standard vehicles like the Thor-Delta and Scout, NASA also decided on a new approach to the cost problem. New technologies of metallurgy, ceramics, avionics, rocket engines and chemistry make a reusable vehicle feasible today when it could not have been economically built a decade ago. The result is the rocket plane called the Space Shuttle, a winged spacecraft with crew compartment, cargo bay, recoverable booster rockets and a large drop tank to contain rocket propellants. It can fly into space, conduct a mission, return to Earth, and fly back into space over and over.

When operational in about four years, the Space Shuttle will be able to boost dozens of satellites into space every year. It will support monthlong expeditions of scientists and engineers in orbit inside a boxcar sized laboratory module called the Spacelab. It will help in launching communications satellites and interplanetary probes, as it can carry upper stage rockets and payloads in its payload bay. By reducing the cost of space flight, the vehicle will open up space to new applications and investigations. Astronomy will be only one of the major beneficiaries.

A routine flight profile may run as follows. The rocket plane blasts off from the modified Saturn 5 launch pads at Cape Canaveral. The delta-winged Orbiter vehicle is the actual spaceplane that carries the cargo and crew and returns to Earth. Attached under its belly is a giant external tank containing propellant for the Orbiter's three main engines — rocket engines of far greater efficiency than the giant Saturn F-1 engines that launched the moon flights. Attached on either side of this external tank are two solid fuel rocket boosters to help lift the vehicle into space. After two minutes of flight, the solid propellant boosters are exhausted and fall away, descending by parachute. They are recovered in the ocean, towed back to Cape Canaveral, and eventually recycled on a later flight.

The Orbiter flies on into space propelled by its three main engines, still attached to the external tank. The tank, when empty, is dropped off just shy of orbital velocity, allowing it to fall back to Earth over a lonely sector of the southern Indian Ocean. The tank is the only major part of the system not returned for reuse. Small onboard maneuvering system rockets push the Orbiter the rest of the way into orbit, where it opens its payload bay doors and begins its mission.

Two pilot-astronauts fly the 100 ton spaceplane. One to five engineers, scientists and technicians may be along on a research task. The crew works and sleeps in rotating shifts for the entire mission, which (depending on requirements) can last from 1 to 30 days.

At flight's end, the Orbiter fires its onboard rocket engines to return to Earth. Despite its streamlined appearance, it does not dive directly into the atmosphere; instead, it performs more of a belly flop, absorbing the 3,000 degree Fahrenheit temperatures of re-entry heat on its special thermal protective system. The ceramic tiles affixed to its belly give it the nickname of "brick airplane"; more sensitive sections of the skin are protected by carbon insulation at the wings' leading edges. For the final few thousand feet, the spacecraft — now a high performance jet aircraft — lines up for a horizontal landing at a three mile long Cape Canaveral airstrip, or at Edwards Air Force Base north of Los Angeles. The approach, normally made under computer control, is a pure glide, since the vehicle has used up the last of its fuel supplies. Risky as this may sound, ground simulations and computer calculations have shown that it is completely safe; similar high speed rocket planes have been landing in like fashion for more than a decade.

The Cape Canaveral airstrip is only a few miles from the vertical assembly building (VAB) where the old Saturn 5s were assembled; if any other airfield in the world is used, the Orbiter is carried piggyback atop a modified 747 transport plane to Cape Canaveral. The vehicle is checked, refurbished, mated to a new external tank and two more recycled solid rocket boosters, and rolled to the launch pad. A new payload is installed in the assembly building or at the pad, and the vehicle is fueled and launched. The time on the ground is a minimal two weeks of normal work shifts; in an emergency, the duration could be shortened considerably.

NASA calls this vehicle *the* Space Shuttle, but "space shuttle" is really a generic name, denoting a whole family of vehicles. Ideally, a space shuttle vehicle must transport men and equipment into orbit with minimal cost and preparation. Low cost today implies a mostly reusable system, but the pendulum may swing back to inexpensive throwaway units, depending on the technologies involved. Low operating expenses for such things as fuel, ground support, recovery crews, and maintenance are also called for. Quick response time may be vital for a space rescue, or investigation of a sudden phenomenon like a supernova. What kinds of space shuttles can be built to satisfy these requirements, assuming a continuing advance in aerospace technology over the next 20 years?

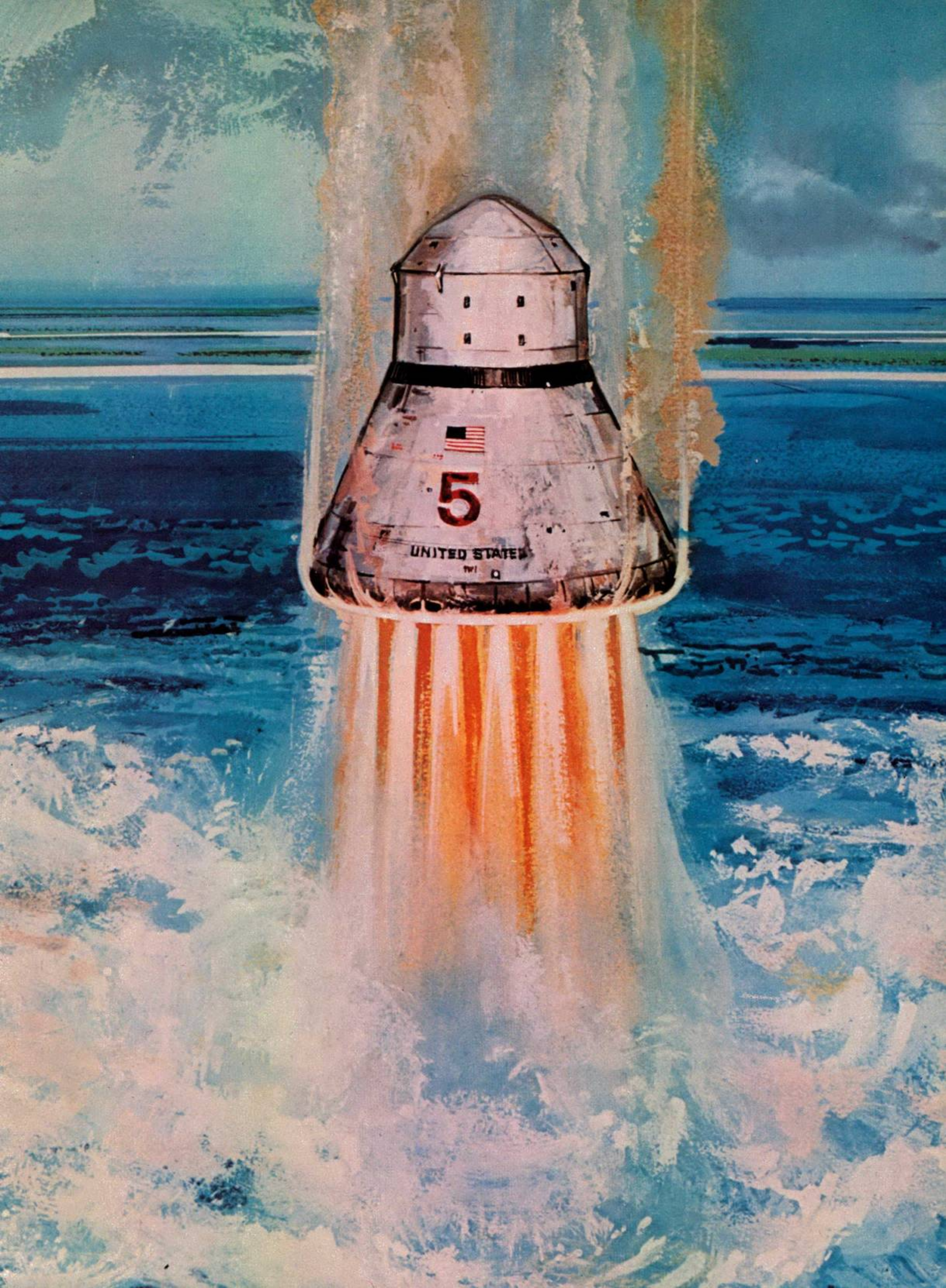
The first step may resemble advanced studies made of two expansions of the current baseline space shuttle project. Once the program becomes operational and a fleet of a half dozen vehicles is built (currently, three are funded with possibilities of two more and options on others), one of the older planes might be taken out of service for test modifications. Alternately, a special model may roll off the production line with the modifications already included.

With powerful new engines available by the mid-1980s, and with an auxiliary fuel tank located where the payload bay is now, such a modified Orbiter vehicle could blast off from Earth and reach orbit without needing the help of solid rocket boosters. It would still have the external fuel tank, which would be carried all the way into orbit; the cost of the solid booster recovery and refurbishment would be eliminated. The thrust of the boosters would be compensated for by a special unit of liquid fuel engines installed at the base of the external tank. In orbit, they could be retrieved in the Orbiter bay or returned to Earth in their own recovery package. The catch is that there is no longer much room or weight allowance for a payload!

The present baseline shuttle can lift up to 65,000 pounds into a low orbit. If one vehicle were modified as described above, it could probably take a two man crew and 5,000 pounds into space. The payload might be stashed in the present passenger compartment (the middeck).

This loss in deliverable payload would be balanced by smaller requirements for ground support and refurbishment — the same area of cost that has so dominated past launch expenses. The new model could launch small scientific or military satellites which require precise orbits and schedules. It could

Several designs for a "vertical takeoff/vertical landing" shuttle are on the drawing boards. One of them is the stumpy vehicle depicted here. It contains two spherical fuel tanks atop a ring of rocket engines, which cushion the last minutes of free-fall descent. The nature of its design allows for little or no payload return, and the shuttle could be manned only by highly skilled crewmen because of high G-forces involved. Boeing Aerospace Corporation artwork.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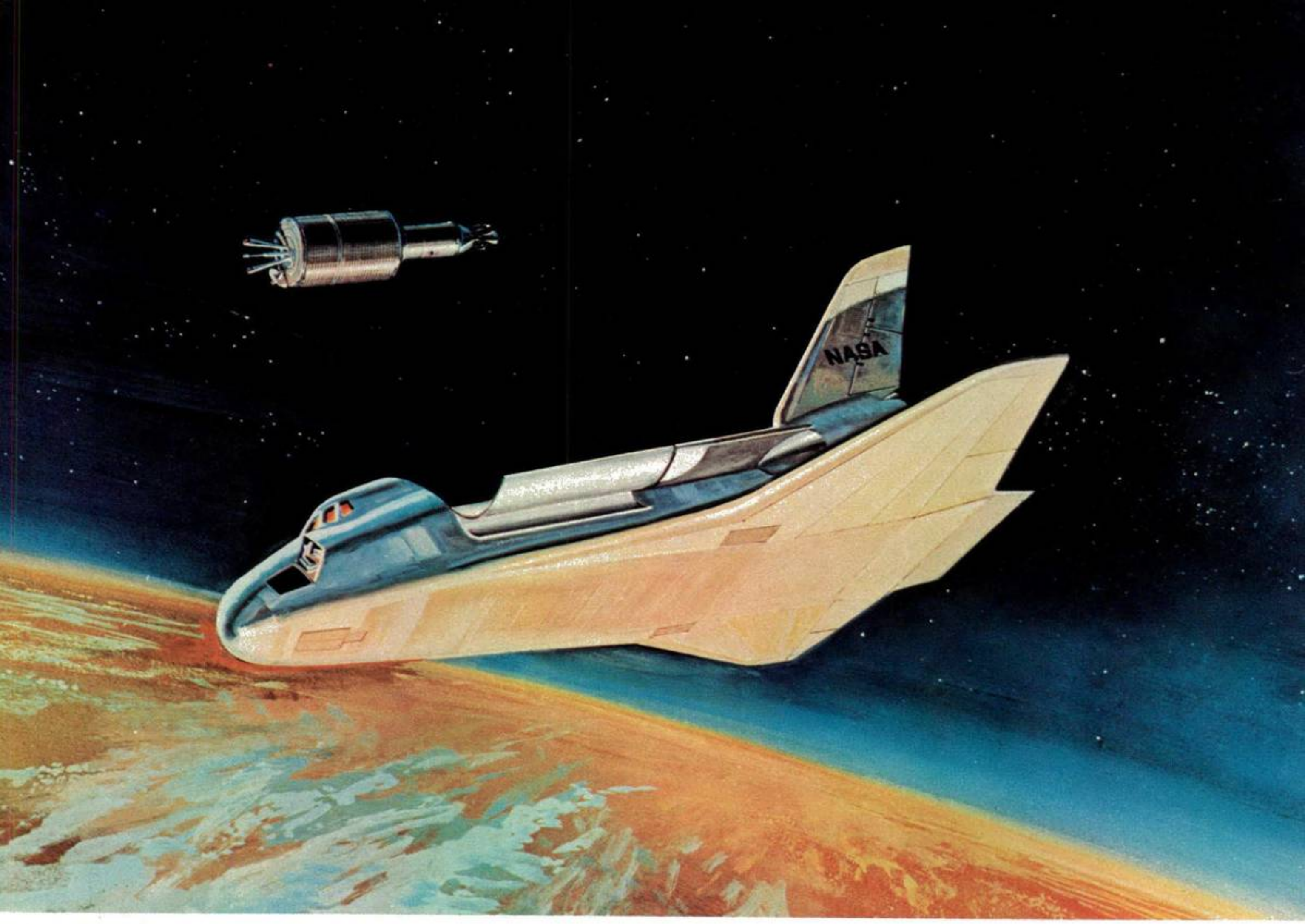


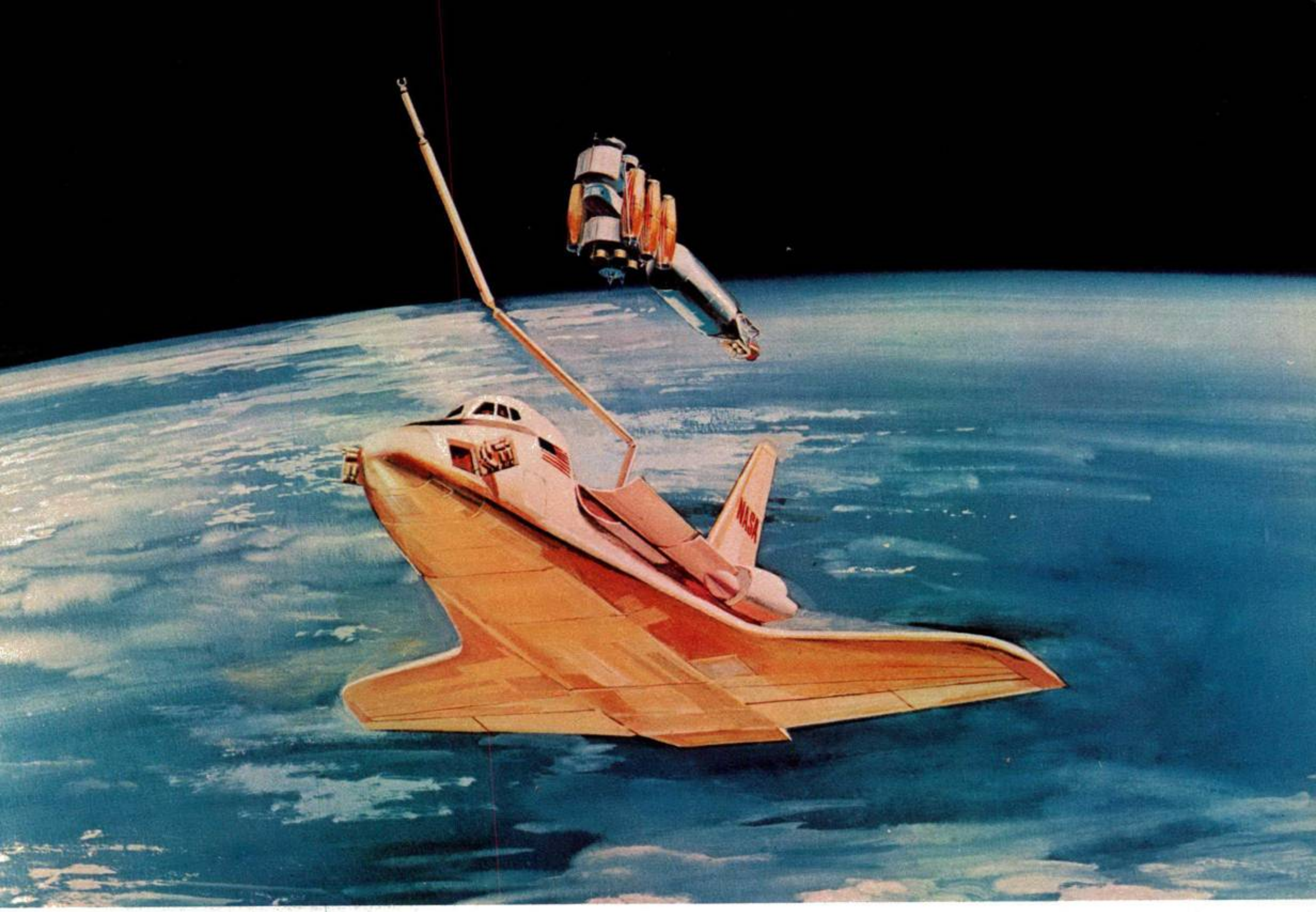
retrieve a sick crewman from a space laboratory. At the very least, the modified Orbiter would serve as a test bed for a later generation of "single stage to orbit" (SSTO) spaceships. If the payload bay fuel tank were removable, this vehicle would have the payload return capability other types of spaceships might need — ships that would not have the large interior cargo holds needed to return payloads from space.

This second space launch vehicle, which could be built as an extension of the basic hardware, could be used if the United States ever needs to lift heavy payloads having integral units weighing more than the 65,000 pound top limit of the standard space shuttle. If there is no need or justification for retrieving these payloads, a large internal cargo hold will not be needed. The payload could save structural weight by riding into orbit atop the space rocket, under a lightweight, expendable shroud — in which case, the winged Orbiter spaceplane may not be necessary at all for this specific application.

One design for such a "heavy lift vehicle" (HLV) calls for a standard external fuel tank with the three engine rocket assembly, normally at the base of the Orbiter, installed below the tank. Strapped to the tank would be two (in larger versions, four) solid rocket boosters; the payload would be placed atop the external tank. Note that all the elements needed to achieve orbit are included, but there is no winged Orbiter — hence, neither crew nor any retrieval capacity. A later Orbiter flight might retrieve the expensive engine assembly if the cost of the retrieval flight were less than the cost of three new engines.

Launch of this HLV booster would proceed just like the launch of the standard space shuttle. Three main engines — now attached to the fuel tank instead of the Orbiter — and the solid rocket boosters would fire together, lifting the HLV into space. The solids would burn out and fall back to Earth for recovery, while the tank and payload fly on into orbit. If the tank is not needed for a space construction project, safety considerations dictate that a small solid fuel rocket be used to deorbit it safely over the Pacific Ocean, lest it fall over a populated area. The engines might be picked up later; alternately, they might be enclosed in a special recovery module of their own and brought back to Earth automatically, leaving the payload in orbit.

The payoff is obvious. Without the need to bring the Orbiter along on what is essentially a one way trip into orbit, the numbers prove out the benefits. A tank, three engines and two solid rocket boosters could place an estimated 159,000 pounds into orbit — almost 2-1/2 times the baseline space shuttle payload. With four boosters (which would fit comfortably without the spaceplane attached) instead of two, the payload goes up to 244,000 pounds — about equal to the lifting power of the obsolete Saturn 5 rocket, but



At left, an Orbiter of the current baseline design releases a satellite into Earth orbit from its payload bay. The vehicle can lift up to 65,000 pounds of varied material into space. A key feature of the space shuttle system is its capability for retrieval; maintenance and repair work can thus be executed in orbit. In the drawing above, the Orbiter extends its long manipulator arms in preparation for satellite recovery. If necessary, the craft can return 25,000 pounds of payload to Earth. The insulation on the plane's belly and wings will protect it from re-entry heat while it performs a computer-controlled glide down to an airstrip several miles in length. Rockwell International Space Division artwork.

at *1/20* the cost! The figures are $180,000,000 versus an estimated $9,000,000 per launch. Remember that these are unmanned vehicles with no payload return and no abort recovery options. All the guidance equipment must also be expendable or in special recovery modules.

This HLV can be used to orbit large sections of space stations, or raw material for space industries. If we ever decide to build an orbiting solar power station, the HLV design will probably serve as the transport vehicle for the thousands of tons of construction materials. Actual construction crews could ride into space inside special space shuttle vehicles with 60 man "passenger modules" installed in their payload bays.

With these improvements over the basic space shuttle in mind, perhaps it is appropriate to take stock of the entire spectrum of capabilities needed for a space transportation system. We are still discussing only transportation from Earth's surface into a low orbit (100 to 400 miles high). To go on from there into higher orbits, or out toward the moon and planets, will require additional rocket stages stored in the payload bay. Eventually a reusable "Space Tug" may fill this duty; for the first two years, a solid fueled Interim Upper Stage (IUS) will be used instead.

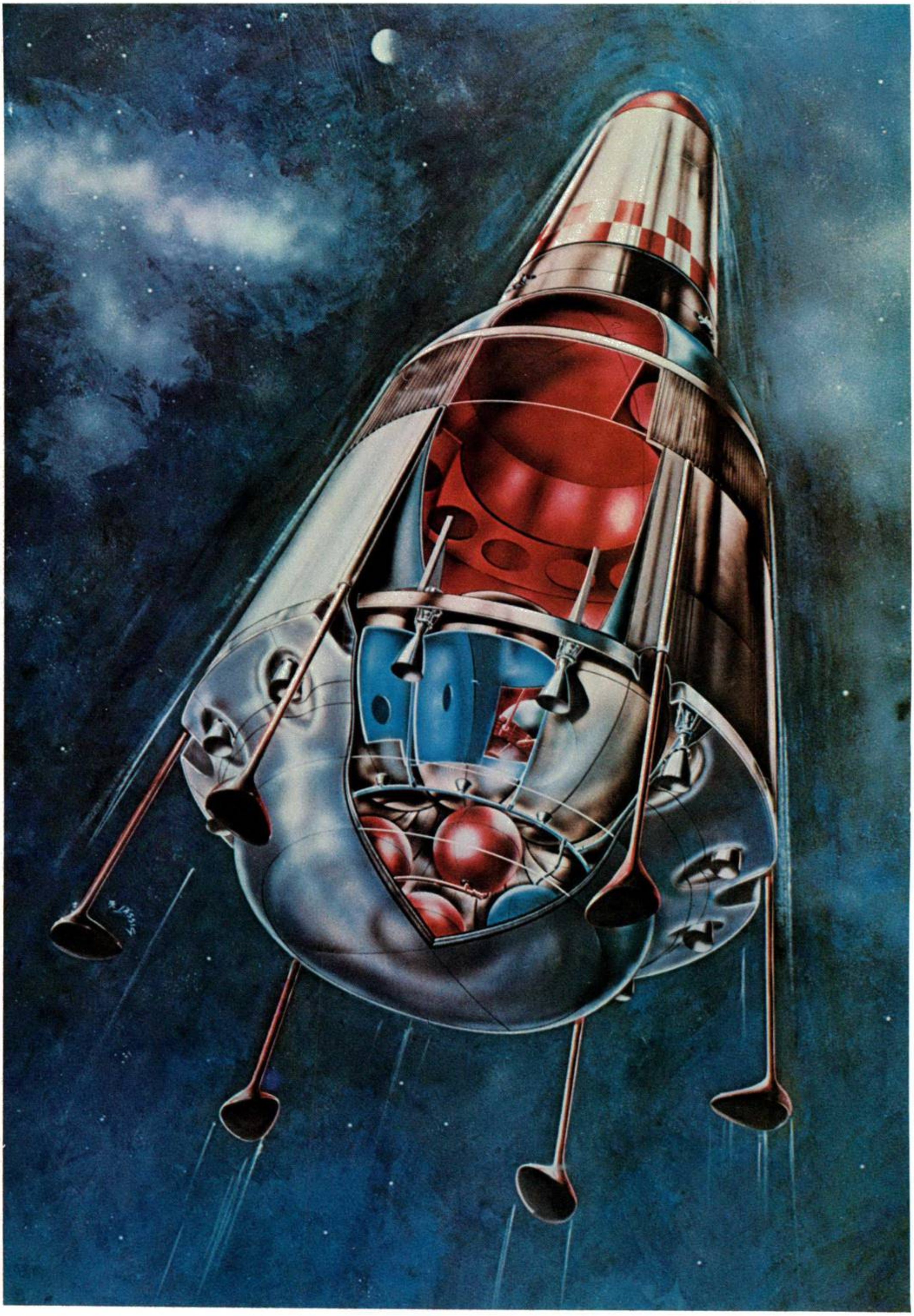
The capabilities of a space shuttle may include any of the following; the present NASA Space Shuttle — being the first, and so far only, one of its kind — must be able to accomplish them all:

1. Vertical takeoff from existing rocket launch sites at Cape Canaveral or from new launch facilities at Vandenberg Air Force Base (Calif.); flight control from the Johnson Space Center in Houston.

2. Stage and a half to orbit (the solid boosters count as a half stage because they ignite with the main engines but are dropped off part way into space), with oxygen/hydrogen fuel.

3. Launch and re-entry G-forces not greater than three Gs (three times the force of gravity), allowing scientists and low cost payloads to ride the vehicle into orbit.

4. Various abort options which save the vehicle and its payload intact. In early phases of boost flight, the space shuttle could turn around and return to launch site, or continue into space for a single pass around Earth prior to landing.



5. Payload delivery and retrieval if desired: 65,000 pounds up but only 32,000 back, due to certain operational safety limits on the final landing glide slope. In an emergency abort, the full payload can come back, but the landing speed is somewhat higher.

6. Large crossrange on re-entry so the vehicle can reach landing points 1,000 miles to the right or left of its flight path. This is accomplished by the high lift of the vehicle's wings, and is required for the "once-around abort" capability and the ability to reach some contingency airfield on any orbit at any time.

7. Normal horizontal landing at a 15,000 foot airfield with standard landing aids. Transportation back to Cape Canaveral would be by air, mounted piggyback atop a special 747 jet.

8. Rapid turnaround on the ground and low maintenance and replacement of equipment between flights. Here is where the major cost saving must be made: in the man hours required to prepare the vehicle for its next flight.

When more than one type of space shuttle is available, every requirement will not have to be satisfied by a single vehicle. The two modified space shuttles mentioned earlier (the SSTO and the HLV) meet some of these basic requisites far better than the baseline NASA Orbiter, but only at the cost of sacrificing other capabilities. It is an instructive exercise to review each of these vehicle designs against the list, item by item.

To meet these requirements in an optimal manner, the 1990s may well see several different types of space shuttles being put into flight service. The Soviet Union, Western Europe, Japan, China and the U.S. will all be capable of designing and building these new spaceships. Depending on mission needs, the U.S. may have several different types of space shuttles, just as it has today many different kinds of transport aircraft. It is conceivable that an aerospace corporation or a consortium might build and operate (for a fee) their own private space transportation system, which could cost less to develop than a supersonic jetliner. What further designs are available for this decade?

The following options (arbitrarily numbered for easier reference) are a few of the dozens of space shuttles being studied today. Some may be feasible and practical within a decade; others may never be built. The important point is that the current so-called NASA Space Shuttle is really only a necessary first step. It is the best design for the 1970s, to be operational by the 1980s. But the '80s will also promise new developments of great importance to future space vehicles; there is no reason to suppose that technological and engineering progress will stop.

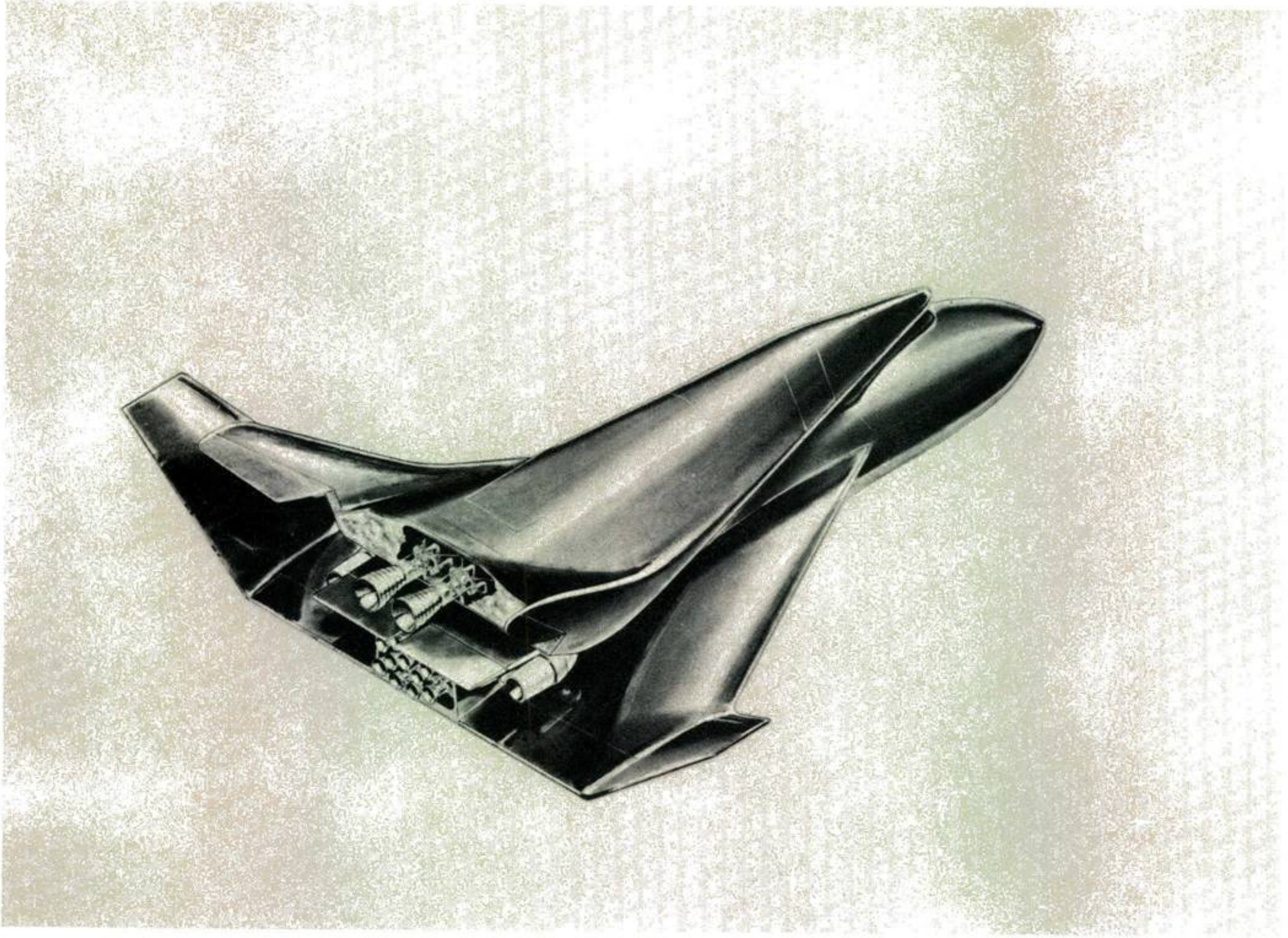
"Project Beta" is the title given a German study for a vertical takeoff/vertical landing launch vehicle. The spacecraft is designed for relatively small payloads of up to 50,000 pounds. Its economy lies in its reusability, but the ballistic entry of this ship leads to very high G-forces, and the design allows little capability for landing guidance at the termination of its mission. Artwork courtesy of Messerschmitt Boelkow Blohm, West Germany.

OPTION ONE. NASA last year awarded a study contract to Boeing Aerospace Company to study a single stage spaceplane, which would take off horizontally like an ordinary airplane and land the same way. The large hydrogen and oxygen tank would be included inside the fuselage, and recovered. The launching would have to be assisted by a rocket sled or "jet-assisted takeoff" (JATO) boosters — which presents the problem of stopping if there is an early engine abort. Furthermore, the great volume of the hydrogen tank adds a tremdous amount of weight to the structure; the cost of this weight may exceed the cost of a disposable tank.

OPTION TWO. Requirements for small payload, quick response missions without payload return might induce the U.S. Air Force to develop an air-launched SSTO one man rocket plane. Based on an outgrowth of X-15 and X-24 technology, this vehicle (the size of a large, jet fighter-bomber) could be carried into the air under the wing of a C-5A aircraft and dropped off at an altitude of about 50,000 feet. The payload, as required, would be carried in an exterior, nonreusable cannister; it could consist of a small navigation or weather satellite, a reconnaissance camera, a package of radiation monitoring instruments, a rescue or medical kit, or a weapons system. Total payload weight would probably be under 1,000 pounds, but the vehicle would be completely reusable. Landing would be at any military air base.

OPTION THREE. Earlier NASA designs for a space shuttle called for a completely reusable winged first stage, as well as a winged second stage. It was not selected for development because of the much higher than expected development costs over the solid booster version now under construction. Readers may still see illustrations of this type of spaceplane in older books and magazines. It might be feasible to build this reusable first stage for the Orbiter vehicle of the 1980s, replacing the throwaway external tank and the solid rocket boosters. However, the cost of developing such a vehicle may be greater than the cost of throwing away many hundreds of fuel tanks (and hence would be "wasteful" to develop). Perhaps by the time NASA could afford to build this reusable first stage, it will have the technology available to redesign the whole space shuttle and build a completely new SSTO model. Again, considerations of economics and technology must be balanced, and many of these questions will not be answered until the present version of the Space Shuttle begins operation.

OPTION FOUR. This exotic approach has been



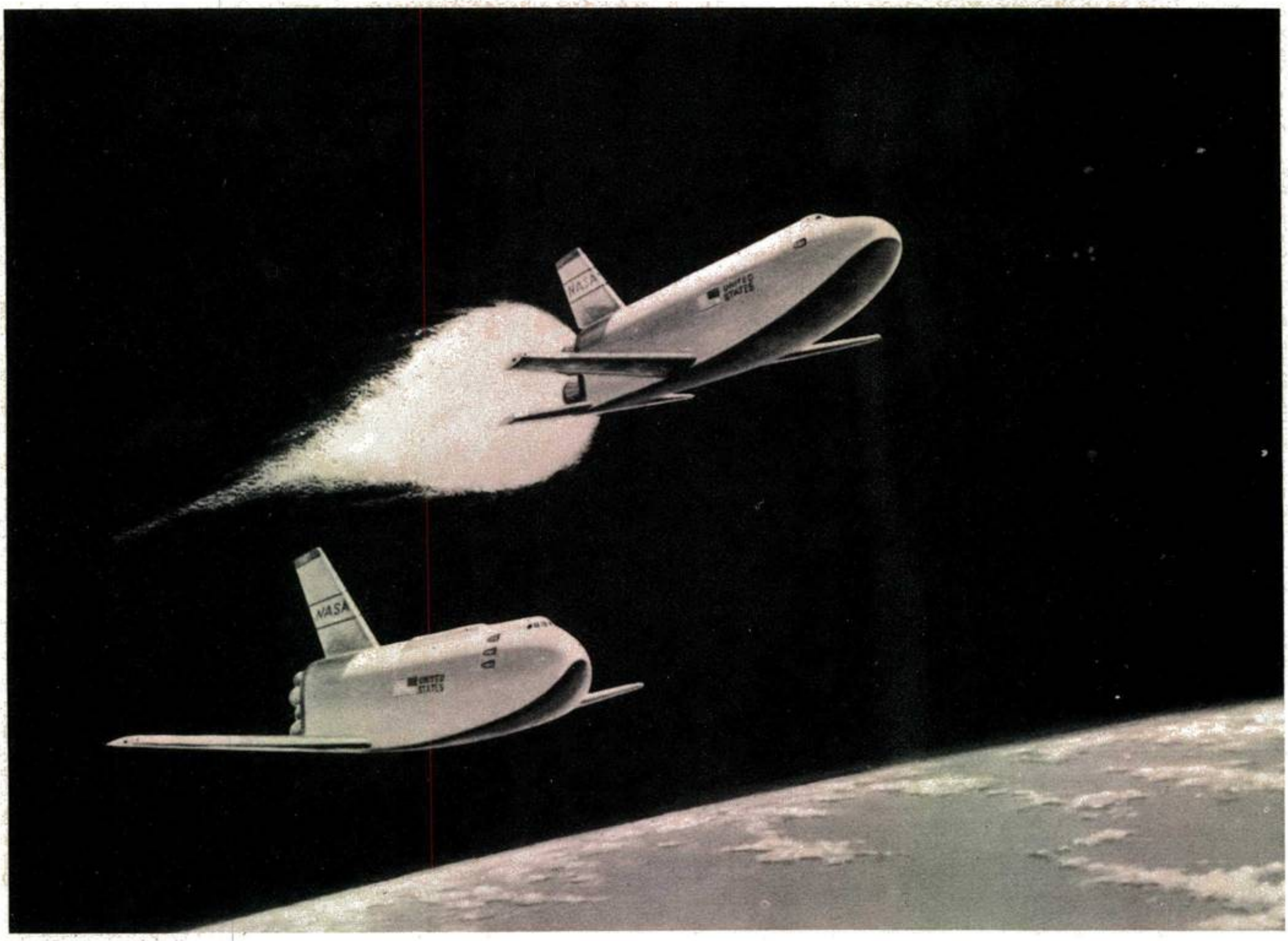
studied in California, Minnesota and Germany. The vehicle would consist of two spherical fuel tanks atop a ring of rocket engines, topped by a small pilot's compartment and an area for securing the payload. The wingless space shuttle would blast off like any other rocket but would land vertically — like an Apollo capsule (by parachute in the ocean) or an Apollo lunar module (by rocket thrust over land). This squat, ungainly looking vehicle could land at sea or in a desert area; the final moments of free-fall descent would be cushioned by firing rocket engines — either the same ones used to blast off or a special set reserved for landing (safer, but more expensive). Rockets are necessary because no parachute could be built large enough to slow the heavy cargo vehicle for a survivable landing.

Little, if any, payload return would be provided by this completely reusable design; the cargo would ride into space atop the booster, protected by an expendable aerodynamic shroud. Launch and landing profiles would dictate a high-G flight regime (four to eight Gs, eliminating all but highly trained astronaut crewmen). No lift on re-entry would mean little if any crossrange, thus requiring a large landing area, perhaps in the ocean or the desert.

These kinds of vehicles could be manned or unmanned. The design is a far cry from the graceful streamlined spaceplanes — but the beauty of the design lies in its economy, not esthetics.

OPTION FIVE. Powerful new engines, using different combinations of fuels for different phases of the ascent, might allow construction of a winged SSTO space shuttle much larger than, but similar in outline to, the present Orbiter vehicle. The problem here (as in other designs) is the thermal and structural protection of the cavernous hydrogen tank; hydrogen is the least dense of all the elements and takes up the most volume for a given weight. The thin wings might not be needed if the vehicle fuselage were in the shape of a "lifting body" — a remarkable rocket plane which generates aerodynamic lift from the shape of its main body instead of from wings. Another problem is the structure of the payload bay: Access could be gained via opening doors in the mid-fuselage, or through a large hatch at the rear of the vehicle just above the rocket engines.

OPTION SIX. The solution to some of the problems in the preceding design is to leave the large hydrogen tank outside the vehicle (build the oxygen tank into the structure), and throw the hydrogen tank away after orbit is reached. This may, at first, seem another example of waste, but the design costs of protecting the tank for reuse may exceed the cost of disposal — and that, by definition, would be more wasteful. Additionally, specialists have suggested that the tank can be used in orbit as a structural element, living space, a storage tank,



A proposal for a fully reusable, two stage space shuttle is shown at left. After takeoff, the larger vehicle releases its piggyback companion into orbit and returns to Earth. An alternate design (above) depicts the separation of the Orbiter from the booster stage. The goal of the space shuttle program is economy of development and operation; reusability, although desirable, is not necessarily compatible with these goals. NASA artwork.

or as "feed stock" for orbital foundries — any one of which would be a definite asset.

The main vehicle of this design would be a narrow pointed vehicle reminiscent of a homemade paper airplane. Perhaps a dozen main engines of the type used in the current Space Shuttle are situated at the base of the craft. Two giant tanks are strapped to either side: One is the expendable hydrogen tank; the other is the protective shell for the 100 ton payload. If payload return capability is needed, this ship design could carry an Orbiter spaceplane into orbit as its payload. The Orbiter would retrieve the desired material, place it in its payload bay, and return to Earth.

Consider an even more powerful flight plan: Suppose this giant space shuttle carried a fully fueled minishuttle like the one described in option two. This smaller spaceship would achieve orbit with a full fuel load! The large launching vehicle returns to Earth alone. By firing its own engines, the minishuttle could reach any part of the Earth-moon system, including lunar orbit or sychronous equatorial orbit. The pilot could perform a scientific, repair, rescue or interception mission. After his flight's completion, the astronaut heads back into the atmosphere and lands the ship under his own control. His re-entry speed would be much higher than normal, thus probably calling for a specially modified vehicle.

Other operations are feasible with these different types of available space shuttles; they are even more powerful in combination than alone. The vertical takeoff and vertical landing (VTOVL) vehicle looks like an old Apollo lunar module: all cabin, fuel tanks and rocket engine. If one were placed in orbit, a series of flights by other vehicles could refuel the vehicle and prepare it for a further voyage. A dozen supply flights could refill its tanks and give it sufficient rocket power to leave orbit, land on the moon and return to Earth. It would make a direct re-entry with an installed heat shield, which might require strengthening due to higher than normal return speeds.

The road to the moon would be reopened by a vehicle which was designed for simple Earth orbital service. Furthermore, the cost of the series of refueling flights would probably be 1/3 to 1/4 that of an Apollo flight, with a lunar payload delivery 10 to 20 times greater than Apollo. Reusability and low maintenance is the key.

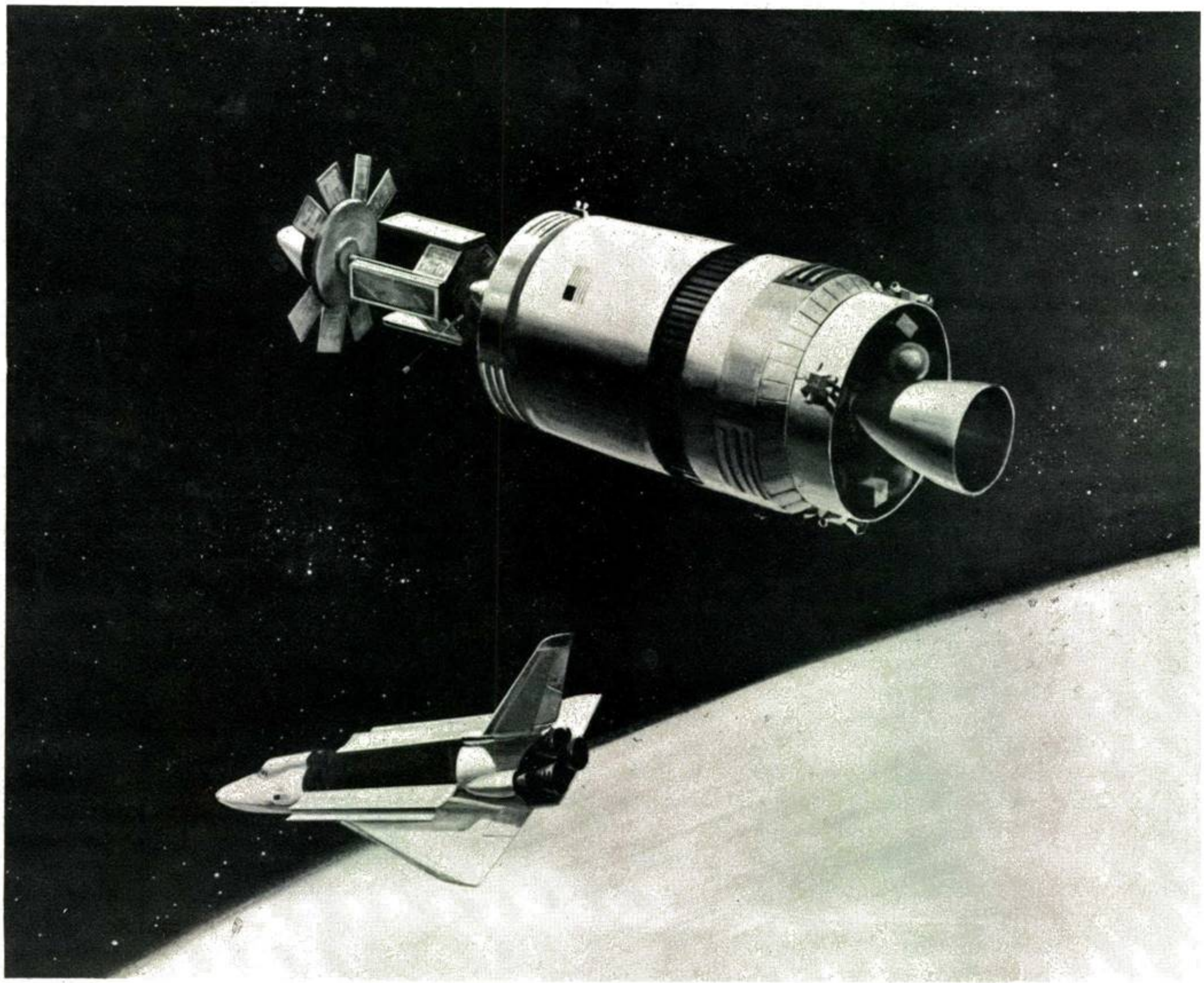
All these options assume that high thrust, chemical burning engines are used to propel the spacecraft. Action-reaction is still the only trick we know, but it has twists we haven't yet tried.

Probably the best propellants for the next 20 years will be liquid oxygen and liquid hydrogen. A common assumption has been that each space vehicle must blast off with all the fuel needed for orbit, because it's always been done this way before. But even this obvious assumption can be questioned. A space shuttle of the 21st century may take off horizontally like a jet airliner of today. It could rendezvous with a tanker aircraft at an altitude of 30,000 feet, and refuel before proceeding into space. Alternately, the vehicle may use a hypersonic ramjet engine early in flight, and scoop up material from the thin, high atmosphere, switching to a rocket engine that burns this newly acquired reaction mass to push it into orbit.

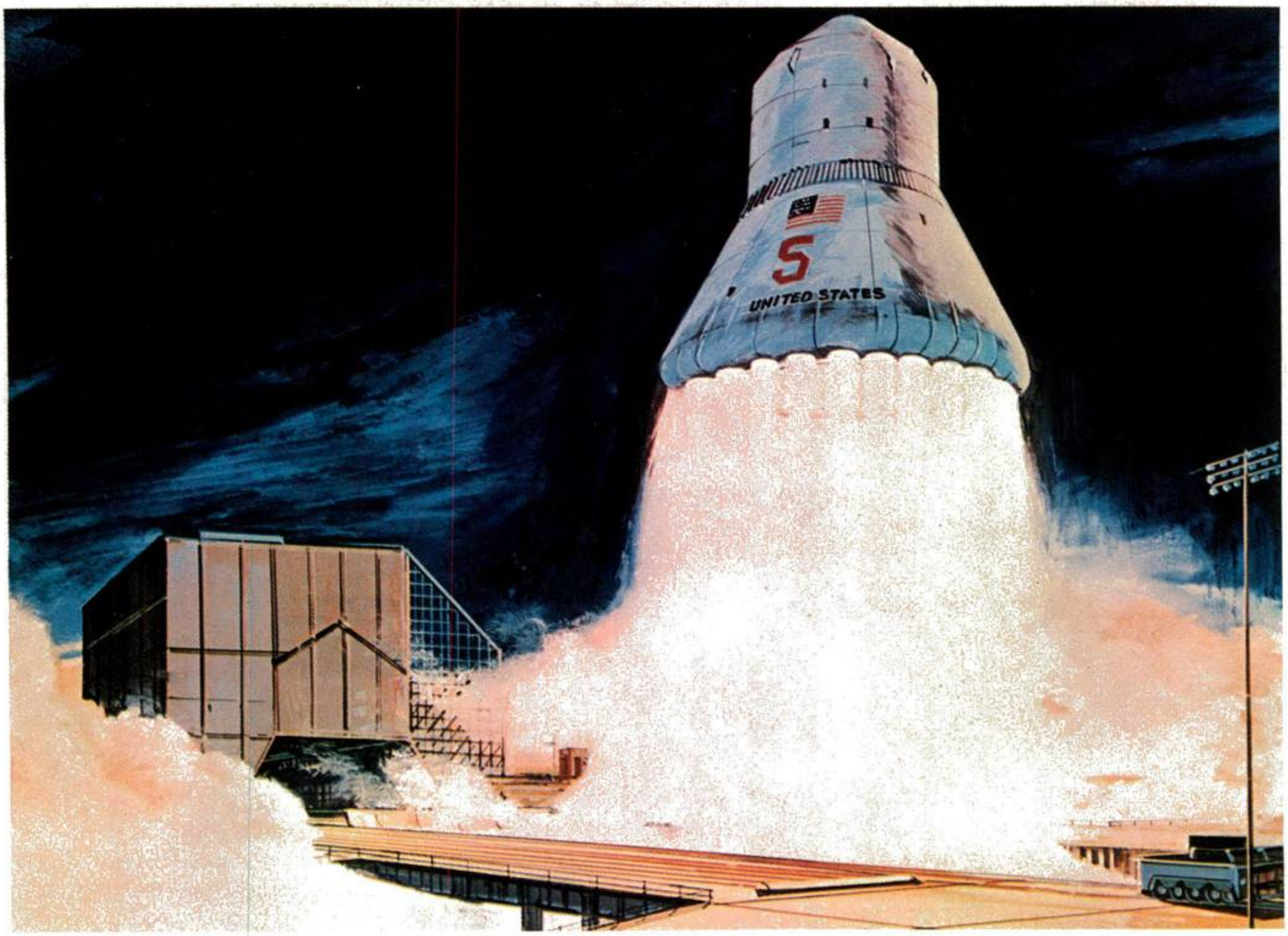
Nuclear rocket power is another alternative often discussed. Various methods for harnessing atomic reactor heat to a space vehicle drive are possible. One technique merely uses the heat of the "atomic pile" to expand an inert fuel and propel it out through a rocket nozzle. Some recent developments along this line may provide the awaited breakthrough. Combined with one or more of the vehicle designs mentioned above, this system might be ready for operational flight by 1990.

One bizarre approach to nuclear propulsion makes use of an idea which has been around almost since the space age began, calling for a giant 500 foot wide thrust chamber; a series of small atomic bombs are exploded inside, one every few seconds. This project was given the code name "Orion" during feasibility studies more than a decade ago; at the time, engineers tested small models with chemical explosives and determined that a rapid fire sequence of blasts could provide nearly uniform thrust. A VTOVL giant space booster of this design might be possible before the end of the century, if "clean" (nonradioactive) nuclear explosives can be perfected. Otherwise, such a booster would be restricted to deep space operation.

Another far-out suggestion involves the so-called long extension cord method of transferring



An Orbiter has just released a second stage rocket from its payload bay in order to place a satellite into orbit. Such secondary boosters will be needed to reach high altitudes beyond the ordinary shuttle's range. NASA artwork.



A "very heavy lift vehicle" begins a trip toward Earth orbit. Its cargo, protected by an expendable shroud, rides atop the booster. This chunky vehicle provides more economy for its job than the familiar streamlined design. Boeing Aerospace Corporation artwork.

energy from a power plant on Earth or in Earth orbit to a rocket in space. Here, the energy is beamed to the spacecraft by a laser beam, transporting the thermal energy directly into the rocket's thrust chamber or alternately by a microwave beam impinging onto an energy collecting "rectenna" on the side of the vehicle. The system would provide only a low thrust, and requires repeated passes over the ground station to build up speed. But it could be used to propel a ship already in Earth orbit onto a path toward the moon. Alternately, the power could be beamed to the spacecraft from an orbiting power station — as long as the high energy beam did not miss the spacecraft and cause damage on Earth below.

There are many other options — perhaps 200 — for space shuttle designs. Technologies still unborn will make space travel an exciting spectrum of engineering challenges for the next few decades, while the currently planned NASA Space Shuttle is opening the beachhead into orbit and is destined to reveal the real value of cheap space transportation. Perhaps later technologies will be developed in space laboratories and workshops.

A half century from now, when many readers of this article will just be retiring from long, productive careers, transportation into orbit will be easy and unspectacular. Perhaps drums of supplies will be flung into the upper atmosphere by electromagnetic accelerators or Jules Verne cannons, where their own rocket engines will carry them on into space. Perhaps small winged vehicles — the size of today's private airplanes — will taxi from hangers and take off directly, powered by thrust devices and energy supplies undreamed of today.

The purpose of transportation, remember, is to reach a destination quickly and cheaply. This is what NASA's current Space Shuttle will pioneer, and it promises to provide excellent and necessary service. But like all vehicles in the fast paced age of flight, it too will eventually become obsolete — but all that means is that someday we'll have an even better way! The Space Shuttle, therefore, is only the first proud vehicle in a limitless family of space shuttles. But it is the first true spaceship — a 20th century galleon of exploration and commerce — plying the road to space. Once again, a revolution, both in science and in everyday life, will follow this new revolution in transportation. All the rhetoric about new frontiers and limitless horizons barely scratches the surface of what space flight and space transportation will mean to mankind. The new road is about to open.

WHISPERS OF THE COSMOS' BIRTH

by
Jeanne Hopkins

The poet T.S. Eliot has said that the world will end not with a bang, but a whimper. While that may be true, it most certainly is not the way it began. The recent discovery and verification of the cosmic microwave background (CMB) seems to provide the long-sought proof that the world began not with a whimper, but a bang — a big bang.

Ranked with quasars and pulsars as the most important discoveries in astronomy during the 1960s, this cosmic background radiation is almost universally believed to be the echo of the big bang itself.

Just as Copernicus showed that Earth moves around the sun, and as Shapley and others later showed that the sun in turn moves around the center of the Milky Way, so the CMB is giving us knowledge of our place in the universe at large for the first time.

Like many other phenomena, the microwave background was discovered, ignored, predicted, rediscovered, and repredicted until finally discovery and prediction meshed.

The first "discovery" of this background radiation (although it was not recognized as such) occurred in 1935. In that year, A. McKellar of Canada's Dominion Astrophysical Observatory was studying the spectrum of a nebula in the constellation of Ophiuchus. The spectrum he saw showed dark absorption lines, which were attributed to interstellar molecules in the line of sight.

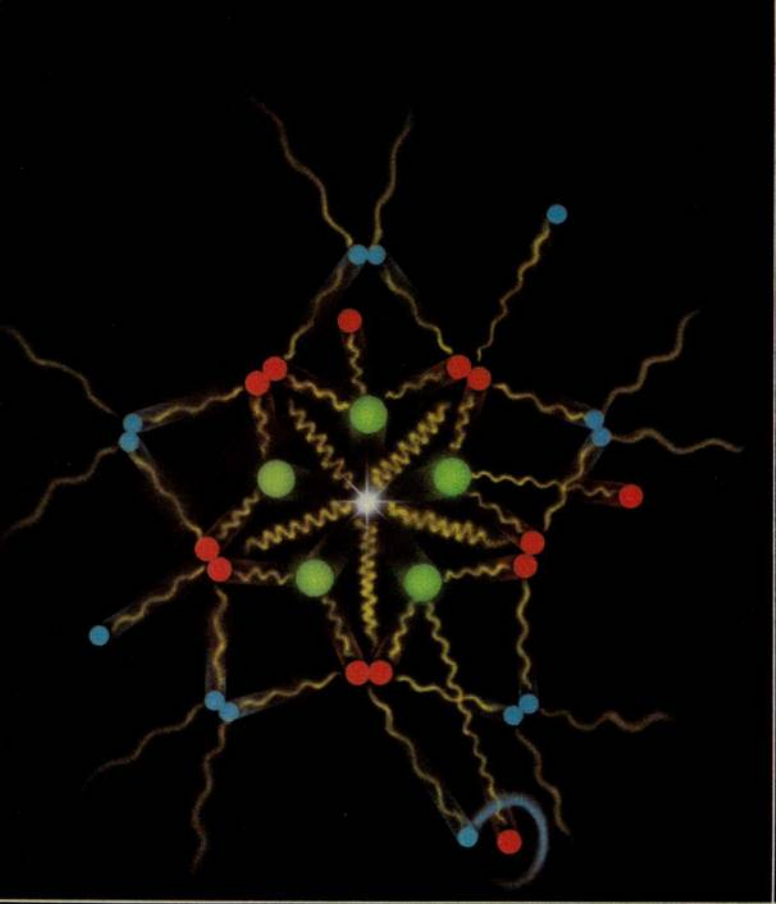
Evidence indicating the presence of interstellar molecules was rare in those days. What made this particular spectrum especially intriguing was that some of those molecules were present in a higher energy state than was expected. In interstellar space, we assume a temperature close to absolute zero (by definition, absolute zero means that all molecular activity ends). However, some of the molecules detected in the spectrum of the Ophiuchus nebula were not in their lowest energy state. Instead, they were shown to be in a higher, rotating energy state.

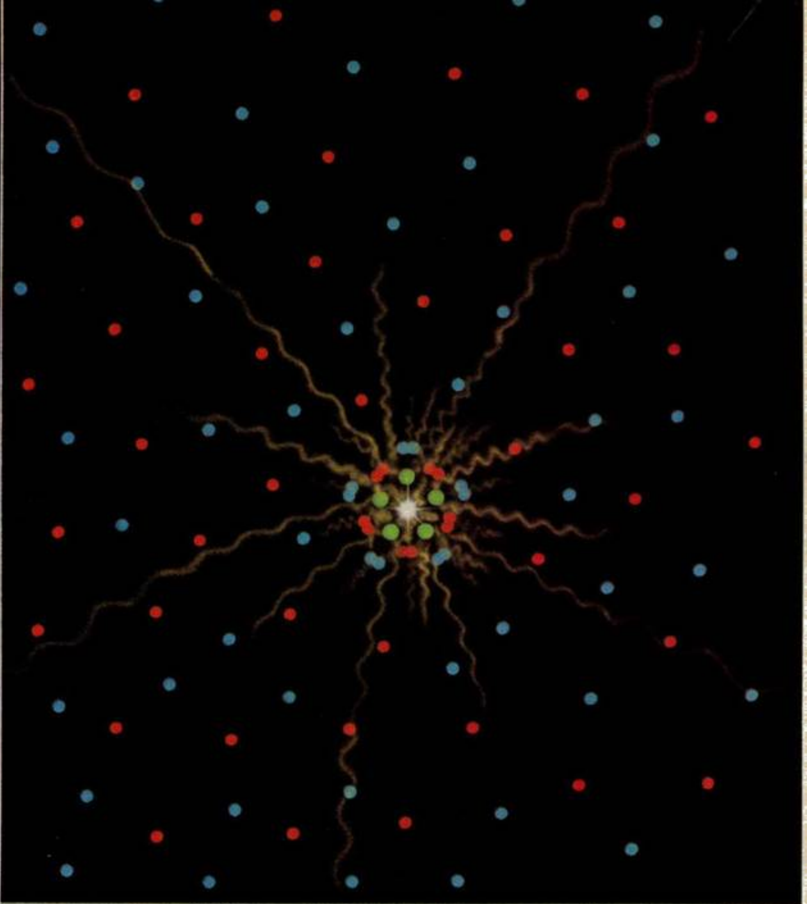
What was providing the energy needed for them to rotate? A number of explanations were advanced. The obvious one was that the molecules were picking up energy through collisions with photons of starlight. In this particular case, though, it was soon proved that such collisions could not maintain these molecules in a rotating state. Something else had to be supplying the energy to produce an environment of a few degrees above absolute zero.

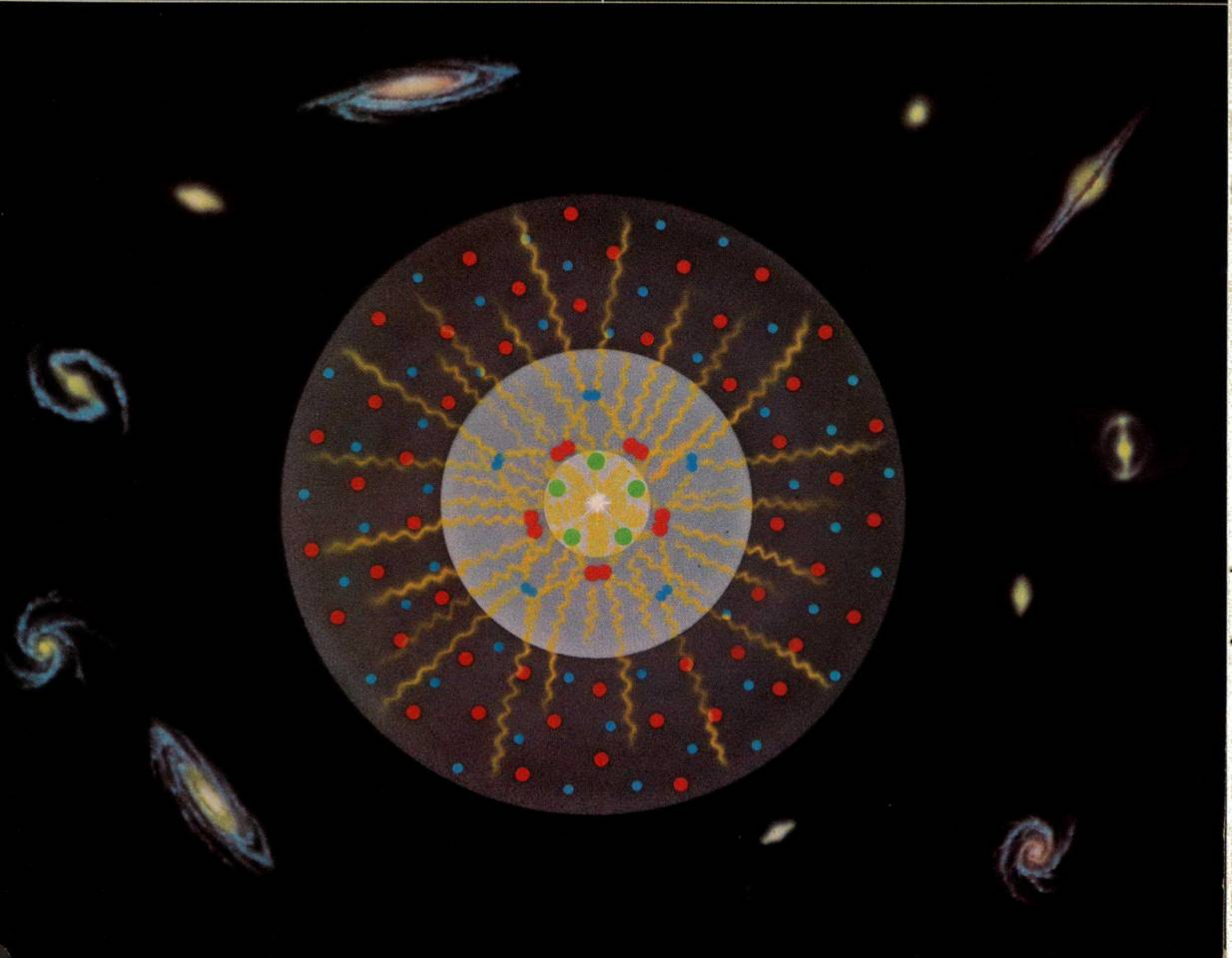
At the time, no one could think of a plausible source for this energy. Therefore, the fact that rotating molecules were present in interstellar space was noted as an interesting peculiarity and promptly forgotten.

In 1948 the late Russian-born American physicist George Gamow predicted that the cosmic microwave background should exist. To understand his prediction, let's go back to the year 1927. In that year the Belgian scientist-priest Georges Lemaître had devised an expanding cosmic model which was consistent with the field equations of Einstein. In this model, the whole universe at time zero was in an ultracondensed state analogous to a giant atomic

What remains today at the site of the big bang? There is no way of telling for certain, but some scientists have theorized the existence of a massive black hole. Such an object can be left after a supernova explosion, and the much more titanic blast that created the universe may well have produced the same thing. The existence of the cosmic microwave background is virtual proof of the cosmological theory that begins with the big bang. Artwork by Victor Costanzo.







nucleus. This cosmic "egg" then "hatched" to become our expanding universe. Gamow called this event the big bang, and the name stuck.

Just after time zero, the universe had two main constituents: exotic, ultramassive particles, and ultrahigh energy gamma rays — present in roughly equal quantities. When the particles collided, they produced gamma rays; when the gamma rays collided, they initially produced protons, neutrons and their antiparticles. However, as the universe expanded and cooled, the gamma rays gradually lost some of their energy so that when they collided, they produced less massive electron-positron pairs, instead of the original proton-antiproton pairs. In a three minute eternity, all but a comparatively few unpaired protons and neutrons were left, and they started to fuse into helium nuclei. Most of the helium on Earth today was probably made then.

Finally, when the fireball had expanded to where it was about a tenth of one percent the size of our present universe, matter could condense out. The radiation left over was too thinly scattered and had too little energy to have any significant destructive effect on matter, and a proton could capture an electron to form a stable hydrogen atom.

In 1948, Gamow predicted that this leftover radiation should still exist. He realized that it would be diluted by the far vaster volume of the present universe and would be greatly redshifted by the continuous expansion of the universe. He originally predicted that the radiation would now be cooled down to a temperature of 25 degrees absolute. In 1956 he revised his estimate to a still-too-high six degrees absolute, but it remained a tremendously accurate forecast!

Unfortunately, Gamow's fantastic prediction was buried in a paper in which he and two colleagues attempted to account for the origin of all elements heavier than hydrogen in the first few minutes after the big bang, by adding neutrons one at a time to a hydrogen nucleus. However, later experiments and calculations by nuclear physicists showed that this could not be done. It is possible for a proton and a neutron to form a nucleus of heavy hydrogen, or deuterium. And two deuterium nuclei will readily fuse to a helium nucleus. But once helium is formed, you reach a dead end. There is no way to fuse two helium nuclei together or to add a proton or a neutron to a helium nucleus. Such particles, if formed, break up in a split second. Since the main premise of Gamow's paper was soon found to be false, the paper fell into disrepute. Consequently, no one in this country took Gamow's prediction of the background radiation very seriously.

This three part diagram illustrates the hypothetical origin of the universe and the cosmic microwave background. At upper left, the big bang creates ultramassive particles (green) and high energy photons. The particles split and produce photons with slightly lower energy, which collide to form proton-antiproton pairs (red). These annihilate to form photons of still lower energy. Again colliding, electron-positron pairs (blue) are produced. When these in turn annihilate, low energy photons are made. (Note that some protons and electrons remain unpaired and can eventually become stable atoms.) The section at upper right depicts a critical crossover time at which matter begins to dominate over radiation — a point reached about 100,000 years after the big bang. At bottom, different eras in the lifespan of the universe are shown. The events in the inner circle are completed within .0001 second; the next takes up to 10 seconds after time zero; the radiation-dominated universe lasts from then until the 100,000 year point; our current universe is represented in the outer circle. The little amount of photons remaining from the big bang forms the cosmic microwave background. Artwork by Victor Costanzo.

Russian scientists were not so single-minded about the paper, however. In 1964, two Russian theorists wrote a paper in which they concluded that the best instrument for detecting Gamow's primeval fireball radiation would be the new 20 foot horn antenna that Bell Laboratories had built in Holmdel, N.J.

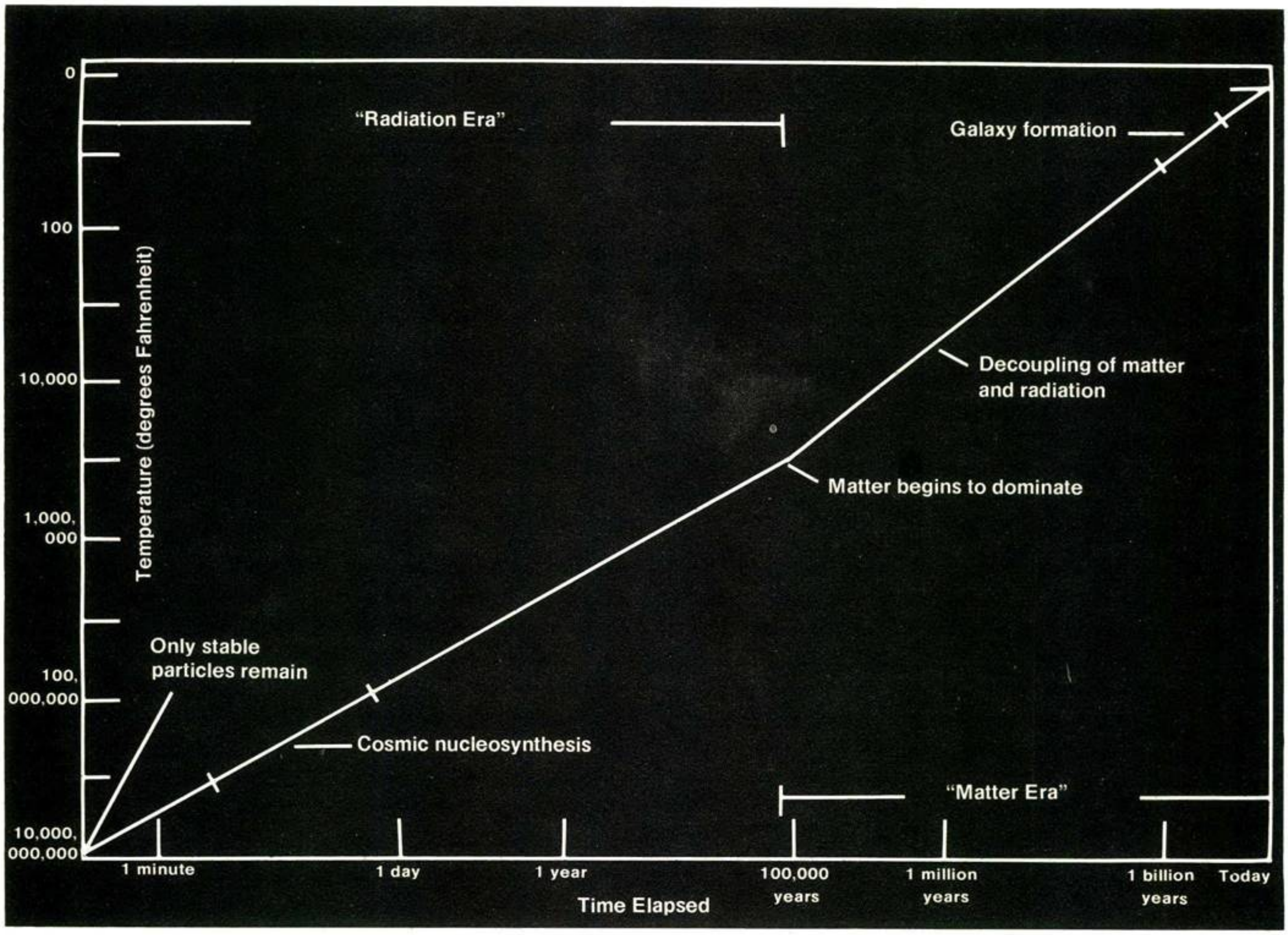
It was at that point, in 1964, that the various paths of prediction and discovery started to mesh. At about the time that the two Russians were polishing up their paper, two scientists at Bell were testing and calibrating the new 20 foot antenna — the same one the Russians had in mind. This highly sophisticated instrument had been designed and built to receive signals from the Telstar communications satellite system. The two scientists, Arno Penzias and Robert Wilson, detected an unexpected hot spot in their antenna. It came uniformly from all parts of the sky and during all times of the day.

Penzias and Wilson accounted for all known sources of radio noise — both terrestrial and extraterrestrial. Even after doing so, the small residual remained — a residual which corresponded to a background temperature of about three degrees above absolute zero. While three degrees absolute may not seem very "hot" (even helium is a liquid at that temperature), it piqued their curiosity because they couldn't account for it.

Although intriguing, the hot spot did not interfere with the operation of the antenna. Since there was no ready explanation, the problem was again put aside. It wasn't until a few months later that a casual remark to a colleague made them realize that they had probably detected the vestigial whimper of the big bang itself. Their discovery has been hailed as the most significant discovery in cosmology since Hubble's discovery of the expanding universe.

But the amazing series of coincidences does not end here. In the early 1960s, Robert Dicke and his associates at Princeton University were studying and discussing the origin of the universe.

They pondered the questions which have vexed man from his first awareness of the world around him. Did the universe really happen only once? Or is our present universe the result of a rebound from a previously collapsing universe? Is a singularity, or region of zero dimensions and infinite density where the known laws of physics break down, inevitable? Or can the singularity be avoided, perhaps by the steady state theory of continuous creation of matter,



The chart above illustrates various phases in the history of the universe. The lower axis represents the time passed from its origins to the present day, while the axis at left gives the temperature of the background radiation remaining from the big bang. Both axes proceed by logarithmic progression, to better portray some of the early stages of the universe's existence. Graph by David A. Schwartz.

or by uniting the theory of quantum mechanics with the general theory of relativity?

Aware that some of these concepts could be tested empirically, Dicke and his team members began to design equipment which would enable them to detect radiation emanating from the earliest period of the universe. By 1964 they had actually built some of their equipment when they received word that Penzias and Wilson, only an hour's drive away from Princeton, had already detected the cosmic background radiation.

As a result, two papers on the subject were published back-to-back in the **Astrophysical Journal**. The first presented the Princeton group's prediction of the existence of the microwave background, while the second described the Penzias-Wilson discovery.

The detection of this cosmic background radiation provided the *coup de grace* to the steady state theory, which had been getting into more and more trouble. Among other things, the steady state theory implies that the universe does not change with time. That is, in any one era there are as many galaxies in a given volume of space as there are in any other era. Unfortunately for the theory, counts of radio sources show that these sources were much more numerous in the past than they are now.

The discovery of quasars a few years earlier had dealt the steady state an almost mortal blow. If quasars are at the distances implied by their redshifts, then they must all have formed in one relatively brief period in the past. This is, of course, contrary to the steady state picture.

The discovery of the microwave background does not prove that the big bang theory is right; however, it does prove that the steady state theory is almost certainly wrong. The cosmic background radiation had been beautifully predicted — even demanded — by the big bang theory, whereas it could not be explained at all under the steady state theory. Even Fred Hoyle, the steady state's most articulate proponent, publicly relinquished his theory in 1965. As he himself had stated through a character in one of his science fiction novels, "Only predictions count in science."

To be sure, a few scientists protested that the "blackbody" character of the microwave radiation had not been proved. In order for the cosmic microwave background to be a remnant of the big bang, it must have a blackbody spectrum. That is, its intensity must increase with decreasing wavelength up to a certain peak, and then decrease sharply. Many measurements of the cosmic background radiation showed the steadily increasing intensity with decreasing wavelength. Unfortunately, the critical point where the spectrum "turns around" lies in the infrared region which is undetectable from the ground.

To measure that part of the spectrum, difficult and expensive attempts were made with balloons and rockets. First results were ambiguous, but in late 1974 a group at Berkeley announced that their balloon experiments had conclusively established that the spectrum indeed turns around at the predicted place.

Determined to have the last word, Hoyle has recently published a radically different explanation of the microwave background. He and his colleague Jayant Narlikar have been working on a reformulation of the general theory of relativity which avoids the singularity, and in which the mass of a particle varies with its position in time and space.

In his most recent paper, Hoyle tries to get around the awkward question of the "origin" of the universe. He proposes that what we think of as the universe is but one part of an ensemble of universes. He speculates that many stars in our universe are fossil relics of stars which existed formerly in another adjacent universe.

Hoyle suggests that light emitted as long as 150 billion years ago by stars and galaxies in an adjacent universe crosses into our universe and becomes the microwave background. Hoyle states in this model, "The usual mysteries concerning the so-called origin of the universe begin to dissolve."

As usual, he has given us interesting material for thought. Also as usual, critics have already attacked his new theory. So the questions remain unanswered. Is the microwave background the remnant of the big bang? Or is it the dying flicker of stars that existed billions of years ago in another universe? Or is there still another model, as yet unconceived, that more accurately reflects reality?

Today radio and space technology is almost to the point where astronomers can measure any small differences that may exist in the strength of the microwave background from different directions. That information may help us determine where we are in the universe. Are we near the center — if there is a center? Or are we near an edge, as Hoyle suggests?

Did all of what we know start with a bang, or with a whimper? Or... neither?

Jeanne Hopkins has been the chief manuscript editor of the ***Astrophysical Journal*** *since 1967. Her book,* ***A Glossary of Astronomy and Astrophysics,*** *is scheduled for publication this spring by the University of Chicago Press.*

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PUBLISHER'S MEMO

ASTRONOMY's editorial department is complete again and twice as big as before. But instead of introducing new people alone this month, the April Publisher's Memo will be devoted to introducing to you all ASTRONOMY employees — with their photographs — and explaining what it is they do and how they are here to serve you.

Thank you for all of your vociferous, enthusiastic support of ASTRONOMY's policy on advertisers as explained in my December 1975 Publisher's Memo. Response was so unexpectedly large to that Memo that it is simply impossible to answer all of the letters we received. Respondents included advertisers, business firms, astronomy clubs and most importantly, individuals — some of whom have never written to a magazine before. Several of the more interesting letters will be published in a future installment of In Focus. Since there was only *one* negative reaction to that Memo, it may be somewhat embarrassing to publish so many glowing letters.

We've discovered from a very dependable source that a company is currently engaged in market research to test the feasibility of selling small backyard observatories to astronomy enthusiasts. We understand that if enough people are interested in buying these small installations, the total package price would be less than $1,000 (minus telescope). If you think this small, prefabricated backyard observatory is a good idea, or if you think you might like to buy one, drop a line to Mr. W. T. Clark, Observa-Dome Laboratories Inc., 371 Commerce Park Dr., Jackson, MS 39205.

By the way, until this time, Observa-Dome has only manufactured large professional size domes for schools and institutions, etc.

This month you'll notice that Gazer's Gazette, Equipment Atlas, Photography in Astronomy and Astronomy Reviews are missing. You'll also notice that Sky Almanac is three times its normal size. A lot is happening in the sky this month which partially accounts for the missing departments and an expanded Sky Almanac. In addition, we've received many *excellent* photographs and eclipse reports from readers which we incorporated in Sky Almanac as well. Never fear, the prodigal departments return as usual to the April issue.

Which brings me to our final point before closing. We love receiving the excellent black and white prints and color slides we have continued to get from readers since ASTRONOMY began. ASTRONOMY will always provide the forum necessary for you to "show off" what you learn about astrophotography. Sky Almanac in particular has become that forum as our response to the growing number of excellent photos we receive from you.

So please don't forget us. Let us see your photos. If they're not up to publication standards we will reject them, naturally (and we aren't able to individually critique rejected ones because of the volume). But at least give us the opportunity to judge their value ourselves. Much too often we have found that readers are far more critical of their own photos than we are.

Plus, what's even better — ASTRONOMY will pay you $7.50 for each black and white print and $10.00 for each color photo of yours we use! Keep the following guidelines in mind:

1. Be sure your name and address are on *each* print or slide.
2. Be sure to include the type of telescope and/or camera used, the manufacturer and brand or model name, as well as all pertinent data concerning the scope/camera hookup. If your telescope is home built, let us know that too.
3. Include return postage, and please allow us at least six to eight weeks to respond.
4. Photos printed on silk textured paper are *rejected* before they even get back from the processor. *DO NOT SUBMIT SILK TEXTURED PRINTS.*
5. If you submit black and white prints, be sure they are well focused and free of fingerprints and dust spots.
6. You don't have to write first, just send the photos. Our payment is for *use* of the photos only. All rights remain your property unless we make other mutually agreeable arrangements prior to publication.

That's all for now. Talk to you next month.

Sincerely,

Stephen A. Walther

Stephen A. Walther
Publisher

INFRARED ASTRONOMY

by
Gerrit L. Verschuur

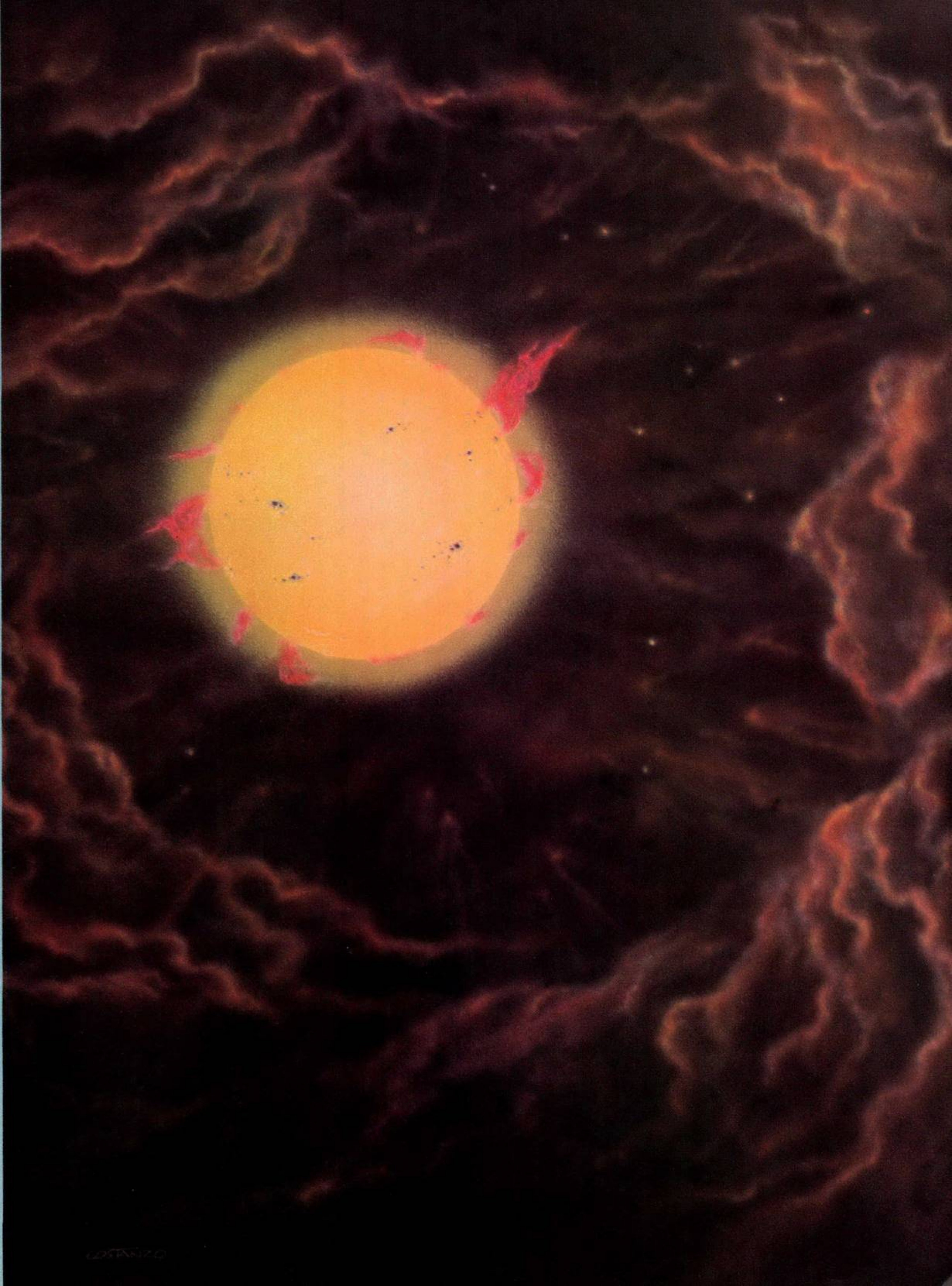
We perceive different kinds of radiation in different ways. Light enables us to see; we can hear signals transmitted over radio waves; most of us, at some time in our lives, have had an x-ray taken to find out what was going on inside our bodies. When we feel heat from the sun, we are sensing *infrared radiation.*

All radiation travels in waves of different lengths. When arranged in order from the shortest to the longest, these wavelengths make up the electromagnetic spectrum. The infrared region falls in the spectrum between visible light and radio waves — hence the name *infrared,* which refers to these waves' position just beyond the red end of the visible part of the spectrum.

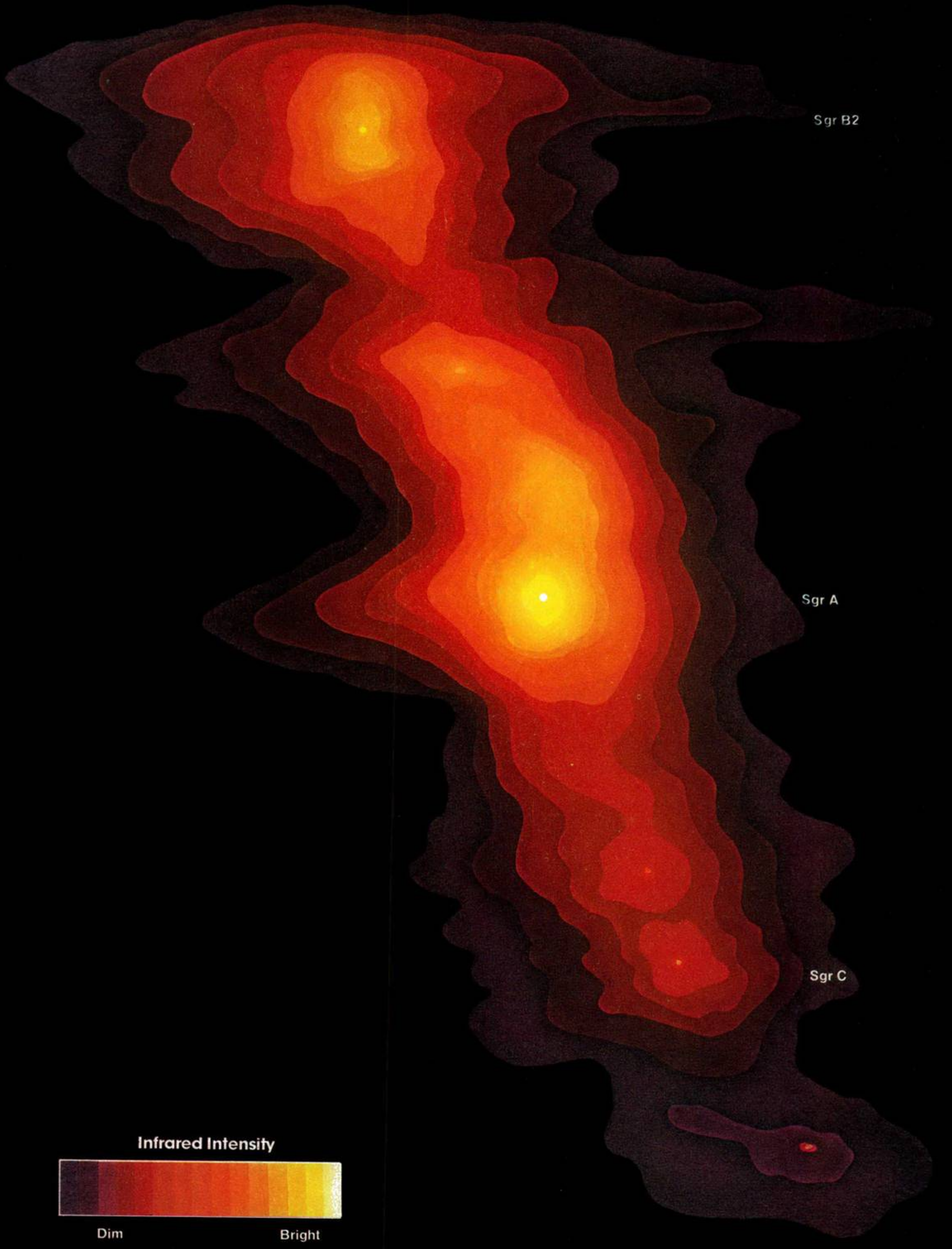
Techniques for detecting radiation that reaches us from space vary, depending on the wavelength. For radio waves, scientists use radio receivers — instruments that are highly specialized. You could not, for instance, pick up radio waves from space on your pocket transistor radio. The visible region of the spectrum can be studied with different light gathering systems, including mirrors, lenses and photographic plates. But since infrared radiation does not significantly affect photographic film (except at wavelengths very close to those of light) and cannot be detected with radio equipment, totally different methods must be used. Basically, an infrared receiver uses a device that is sensitive to heat; in the presence of some heat radiation, its electrical resistance changes. These changes, when measured, indicate the amount of infrared reaching the instrument. The heat sensitive device is called a *bolometer.*

Infrared telescopes can be manufactured from bolometers used in conjunction with mirrors. Unlike their optical counterparts, however, these can detect infrared radiation only from a specific point at any one time; the infrared telescope cannot record images of many stars on a single photographic plate. To study the infrared universe, astronomers must scan a given region of the sky with their telescopes systematically checking one tiny spot after another. Needless to say, this can be a very tedious process —

After a star coalesces from the immense clouds of gas and dust that are its birthplace, it may still be enclosed within enormous layers of dust. This material can absorb some or all of the star's visible radiation. But inside the cloud, the high temperature of the newborn star heats the dust, and this heat is reradiated out into space. Interstellar dust particles are usually good reflectors of heat, and we on Earth detect it as infrared radiation. In fact, we can locate a totally unseen object solely by its infrared output. Eventually the dust may clear away and reveal the star — or it may envelop the star throughout its entire lifetime. Artwork by Victor Costanzo.


COSTANZO

Milky Way Center in Infrared



although the method is similar to that used in making surveys of the sky at radio wavelengths.

An additional difficulty facing astronomers is the absorption of infrared by the water vapor or carbon dioxide in Earth's atmosphere. To carry out most experiments, scientists must send their telescopes as high, and above as much of the atmosphere, as possible. Since some infrared radiation does leak through at specific wavelengths (called *windows*), the first infrared telescopes were usually modifications of optical instruments located on high mountains. And even so, observations through these windows were virtually useless when studying fainter objects, because Earth's atmosphere itself radiated sufficient heat to block the tenuous infrared from these sources.

Consequently, adequate study of infrared wavelengths required scientists to send their experiments above much of Earth's infrared-radiating atmosphere aboard high altitude balloons. But the flying time of a balloon is very limited, and the brief glimpses into space possible under such conditions were more frustrating than rewarding. Later, when the era of jet planes began, high-flying jets were specially equipped with infrared detectors built into the planes' sides. But again, planes have to land some time, and the infrared telescope could not be used for indefinite periods. Today, infrared telescopes can be included in the equipment sent into orbit aboard satellites; astronomers are finally receiving a totally unobscured look at the radiation before it hits Earth's atmosphere.

Earliest infrared experiments concentrated on objects in the solar system. This was only natural, for the sun is (as we might expect) our most powerful source of infrared radiation — at least 100,000 times as bright as the moon, the second strongest source.

Naturally, the moon does not radiate its own energy. How, then, is it possible for it to be such a strong source of infrared? The answer is implicit in that the moon shines by reflected sunlight. In fact, the reflected visible light from the moon is less than 1/10 as strong as its infrared glow — indicating that much of the infrared radiation we detect from other sources may be due to reflection and not original emission. Asteroids and other planetary bodies also are much brighter in infrared than in visible light. By measuring these emissions, scientists can find a planet's *infrared temperature* — the temperature of its visible surface, whether solid like Mars and Mercury or cloudlike as with Venus and the gas giants.

This artist's rendering of an actual contour graph portrays the intensity of infrared radiation from the center of our galaxy. The region called Sagittarius A is also the chief source of radio waves from the Milky Way; both types of radiation are almost certainly associated with the galaxy's nucleus. Other concentrations of infrared are referred to as Sagittarius B2 and C. The use of color in this painting is a device to indicate infrared brightness; the colors are not seen in the sky. A seemingly large section of the Milky Way is depicted here, but in fact the graph covers a tiny area of the sky less than two degrees of arc across. Artwork by Mark Paternostro.

Outside the solar system, we find more than 6,000 known sources of strong infrared emission. Most are located in the Milky Way itself with about 10 percent of our galaxy's total emitted radiation falling within the infrared region.

Sources of infrared are many and varied, but two basic types can be discerned: stars situated (from our viewpoint) behind dense interstellar dust, and dense clouds of dust actually surrounding and being heated by unobservable stars. In the latter case, the stars are detected because of reradiated infrared wavelengths rather than radiation from the original sources.

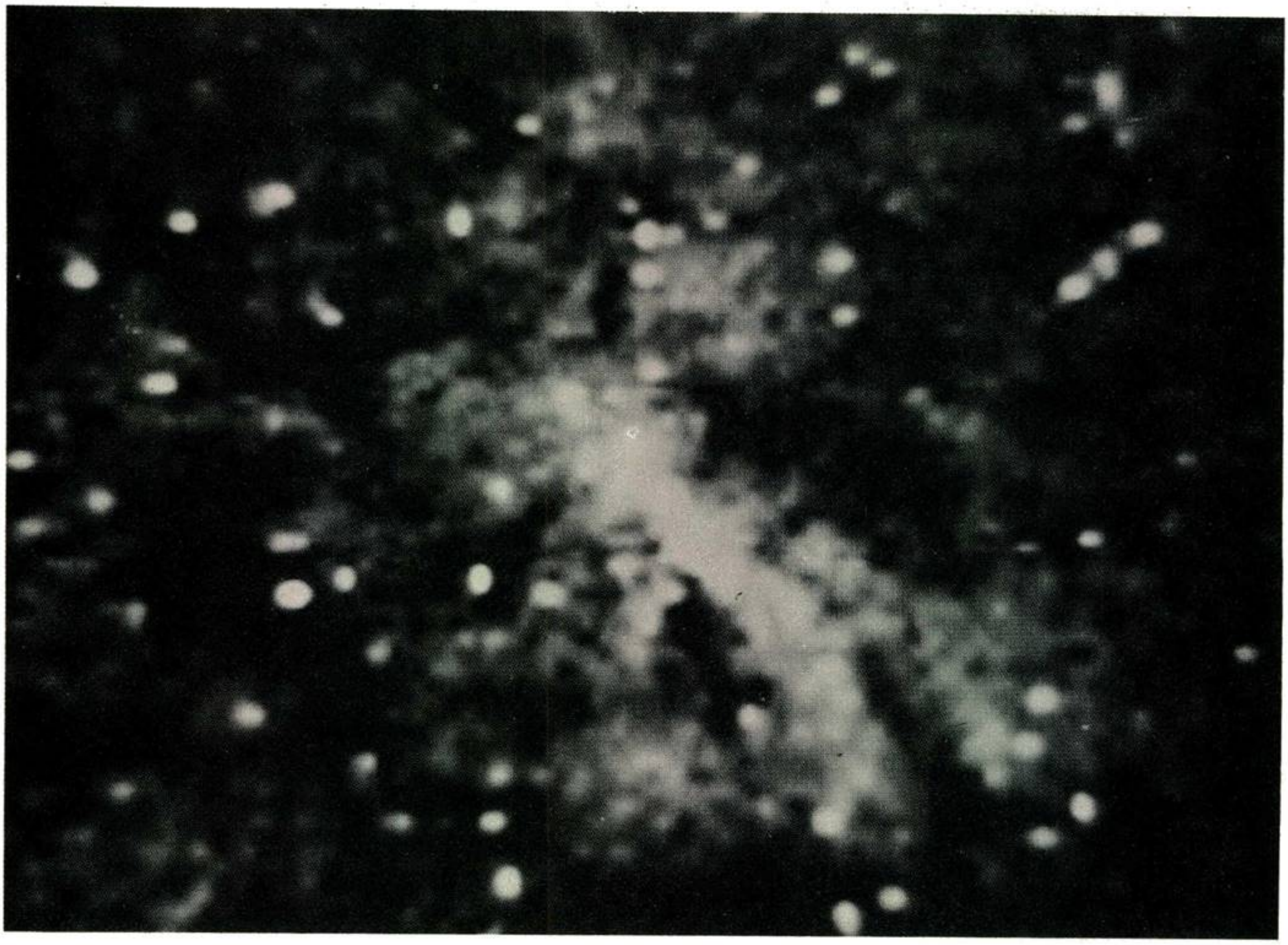
In the first case, a very bright but otherwise perfectly normal star must be situated behind so much dust that all its visible light is blocked from view by a heavy conglomeration of dust particles. These particles, like our moon, are poor absorbers (good reflectors, of infrared radiation) so the infrared radiation "leaks" through, eventually reaching Earth where we can detect it with the necessary instruments. Although at first we might think we have found an unusual infrared object, it turns out to be a normal star seen — or unseen — through a thick dust cloud.

The other usual type of infrared emitter is a star surrounded by its own personal dust cloud, from which it has just formed. The unabsorbed dust still swirling about might coalesce into planets at a later date. But in the meantime, the star is heating this surrounding dust envelope. It is the reradiated infrared heat from the dust itself that we detect.

Such dust shells do not always originate in leftover material from star formation. In some cases, the shells may have been ejected from the star itself, much the same way planetary nebulae are formed; after being heated by stellar radiation, they are detectable infrared sources. Here too, the shell absorbs the star's visible and ultraviolet radiation, making the star itself invisible. Some of these dust envelopes are very large — as much as 20 times the diameter of our solar system — and the temperature of the dust is only about 100 degrees above absolute zero.

Other types of stars found in the infrared source list include long-period variables and novae — both of which appear to have associated dust shells. A class of stars known as carbon stars are also strong emitters of infrared. The youngest known stars — T Tauri stars — also have surrounding shells of matter. In this latter case, the shells may have formed from gas and dust thrown out by the stars soon after they began shining.

Some of the most interesting infrared sources in the galaxy are those associated with radio emissions from molecules of hydroxyl (OH — a combination of oxygen and hydrogen). These OH sources emit very strong radio signals, the strength of which can only be explained if the hydroxyl molecules themselves are bathed in infrared radiation. As the molecules absorb energy from the infrared, they reradiate that



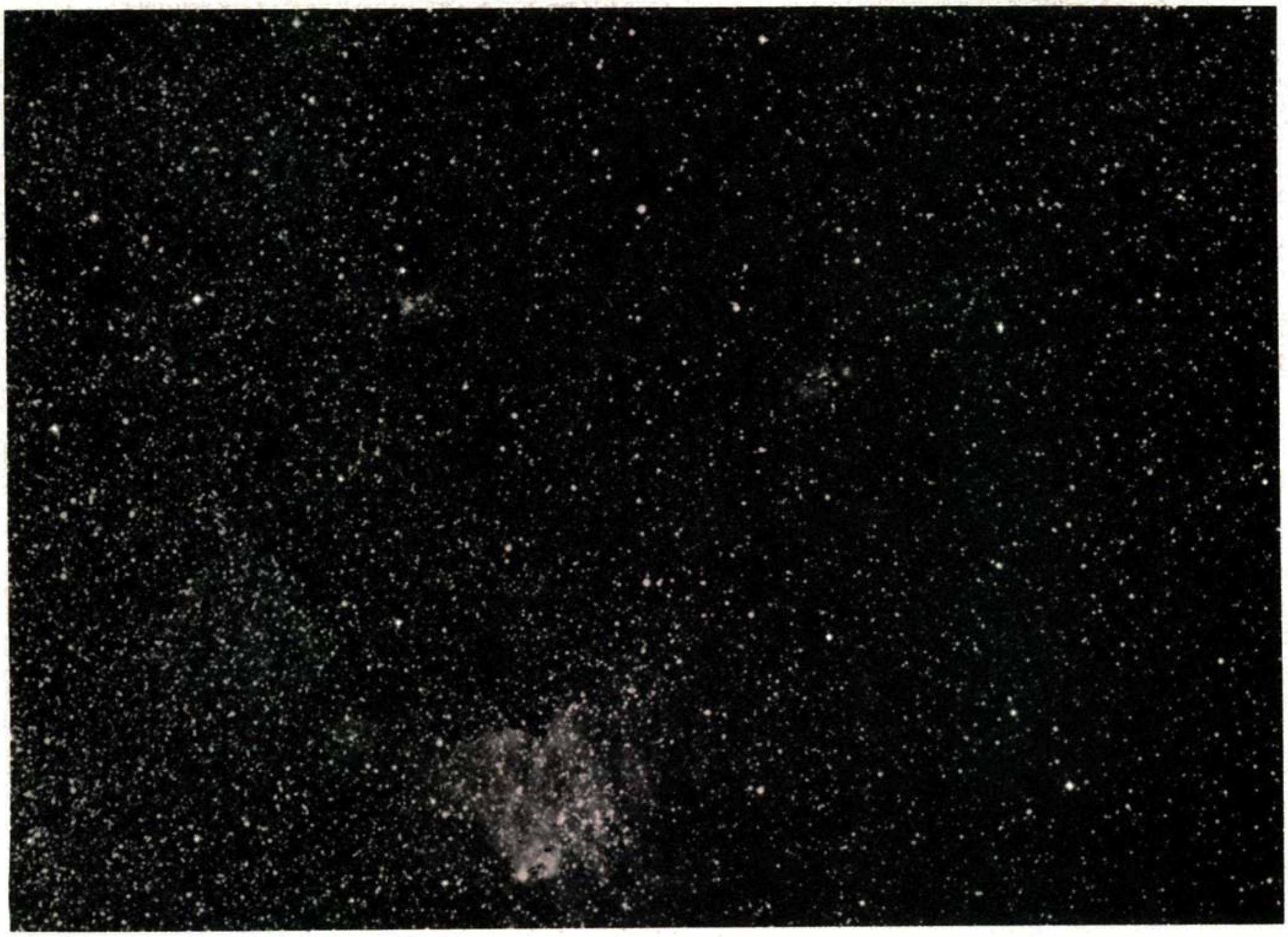
extra energy as radio waves in a process referred to as *maser amplification.*

Recent studies have shown that many objects emit much more infrared than does a normal star. The list of such objects includes very old stars, very young (and possibly unborn) stars, galaxies and quasars. The most important of these sources are the young stars — some of which apparently are going through the final stages of star birth. At this time, these objects (called *protostars*) have not yet turned on their own nuclear furnaces. Protostars are hot only because they are still shrinking and it is this shrinking process that generates heat. Several infrared sources have been discovered near emission nebulae (such as the Orion nebula). They have temperatures of only a few hundred degrees and are probably protostars.

The center of our Milky Way galaxy in an area about one degree across is another strong infrared source. Blocked from our view by immense dust clouds, the source of this great infrared outpouring is probably an enormous conglomeration of stars at the heart of the Milky Way. This infrared radiation is also associated with Sagittarius A — the central radio source of the galaxy — and the two are most likely one and the same. A larger region (about four degrees long and two degrees wide) surrounds this area and also emits much infrared, although not in such great quantities as the main source. The cause of this radiation emission of heat may be from dust clouds encasing the stars at the galaxy's core. A similar infrared source is found in our neighboring galaxy, M-31.

Dr. Eric Becklin of the California Institute of Technology has recently provided a totally new view of the galactic center with a photograph taken at infrared wavelengths. We have mentioned that infrared detectors are quite unlike the analogous optical instruments, so the word "photograph" is used here very loosely. To obtain this image, an infrared telescope was scanned over the Sagittarius region of the Milky Way. As work progressed, the resulting data was recorded in a raster pattern, much as a television image is produced by a scanning electron beam inside the picture tube. After the data was computer processed, an image was fed onto a television screen and photographed, producing a photo of the infrared radiation from the center of our galaxy.

The infrared photo has a very different appearance from optical pictures of the same area. The objects visible in the infrared picture are some 30,000 light-years distant; the stars in an optical photograph of this area are only a few thousand light-years away. Many stars emitting infrared are visible on the computer photograph, but dark areas indicate the existence of dust clouds so dense that they absorb even the infrared radiation from the stars behind them. Slight fuzziness in the photo is due to the poor



The photograph on the opposite page — actually a computer-generated television image — is a picture taken at infrared wavelengths of the center of the galaxy. Because an infrared telescope is so different from its optical counterpart, the word "photograph" is used loosely. The picture was obtained by scanning an infrared detector over the Sagittarius region of the Milky Way. After computer processing the acquired data, an image was fed onto a television screen and photographed. Note the vast difference between this picture and the one above, obtained by an optical instrument. Dark areas on both photos indicate the presence of dust clouds. Those in the infrared photo must be extremely dense, since they seem to absorb even the infrared radiation from objects behind them. Opposite: Photograph by Eric Becklin and Gary Neugebauer. Above: Hale Observatories photograph.

resolution of the infrared telescope as compared to an optical instrument.

Two more very unusual infrared objects found near the central plane of the Milky Way are called Maffei One and Two (after their discoverer). Not starlike in shape or size, they cover a few minutes of arc in the sky. Studies show that these two objects are galaxies located very near our Milky Way and situated in the same direction as the galactic core. Although visible light from Maffei One and Two cannot reach us, their infrared emission manages to penetrate and can be detected on Earth. Since their infrared discovery scientists have also detected radio signals from Maffei objects which may mean they are elliptical galaxies located three to four million light-years away.

Other normal galaxies emit infrared radiation in ways similar to the Milky Way. Objects known as Seyfert galaxies, however, show much more infrared radiation than is usual. In fact, the total infrared energy output of Seyferts can exceed their emission of all other wavelengths combined. But Seyfert galaxies are not normal objects in the first place Violent explosions or similar phenomena seem to occur in their central cores which result in intense light radiation. In addition, intense radio and infrared radiation from Seyfert galaxies, generated by cosmic ray particles spiraling around magnetic fields, make these infrared sources very different from any of those found in our galaxy.

Because so much of infrared radiation is absorbed by Earth's atmosphere, intensive research into the field has only recently begun. As long as mankind was limited to the observations he could make from our planet's surface, he could have no idea of the knowledge that awaited him above the atmosphere's protective shield. Infrared astronomy is an area that can truly be called a child of the space age.

Dr. Verschuur is a regular contributor to ASTRONOMY. He is director of the Fiske Planetarium and a professor in the department of astrogeophysics, both at the University of Colorado in Boulder. In addition to over 50 published scientific articles, he has contributed "The Interstellar Medium" to the 1973-74 edition of ***Encyclopaedia Britannica*** *and is author of* ***The Invisible Universe*** *(Springer-Verlag, New York, 1974), a layman's introduction to radio astronomy.*

SKY ALMANAC

Only Mercury's Not Around

If you like observing the various members of the solar system, you'll love the March sky. Every planet except Mercury is visible this month in a sort of celestial traffic jam. Even though the four brightest planets are all moving away from Earth, they are still available for telescopic viewing. Several of their dimmer companions, including Juno, Uranus and Pluto, are at or near opposition and present different kinds of challenges to the observer. To top everything off, comet West, just past perihelion, is in its best position for viewing.

Comet West (1975n)

Early observations of comet West indicate that it is even brighter than expected. At the beginning of this year, it was measured at magnitude 9.5 — a full magnitude brighter than original estimates had predicted.

Does this mean we can expect comet West to look like a searchlight beacon in the morning skies of early March? Brian Marsden of the Smithsonian Astrophysical Laboratory warns that it might not hold up; comet West is exhibiting the same behavior that the notorious comet Kohoutek showed before its closest approach to the sun. Like Kohoutek, West may be experiencing its first passage through the solar system. But there is still hope; the orbit calculated for West will not bring it as near the sun as Kohoutek, and it may not suffer the same fate.

If comet West does behave as expected, it should provide a glorious sight in the dawn twilight during the first days of March and get your month's observing program off to a good start. (See last month's Sky Almanac for details on viewing the comet.)

Juno

In general, 1976 is not a particularly good year for observing the major asteroids. The only one of the "big four" reaching opposition this year is Juno, on March 1.

Although Juno's orbit is not a very eccentric one as far as other asteroids go, neither does it travel in the near-circular path of a major planet. Its distance from the sun at perihelion is 184 million miles; at aphelion, 312 million miles. During opposition, Juno will be close to its average distance, 155 million miles from Earth.

The orbit of Juno is inclined to the ecliptic by 13 degrees, explaining why Juno will be located in the dim constellation Sextans, south of Leo, at opposition. Later in the month it will return to Leo and stay there until July. (See the accompanying map for details.)

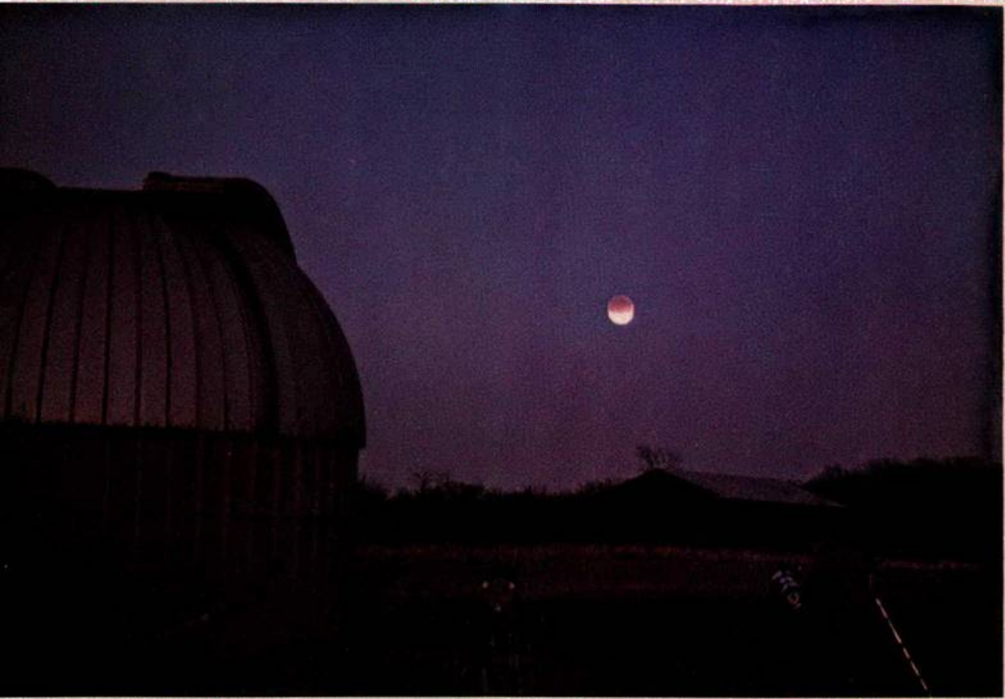
We obtain our best views of Juno when perihelion coincides with opposition. As this is not the case in 1976, the tiny (155 mile diameter) planet will achieve a maximum magnitude of only 8.7. Juno is the dimmest of the "big four" in any case, and you'll need at least a 2.4 inch refractor to see it.

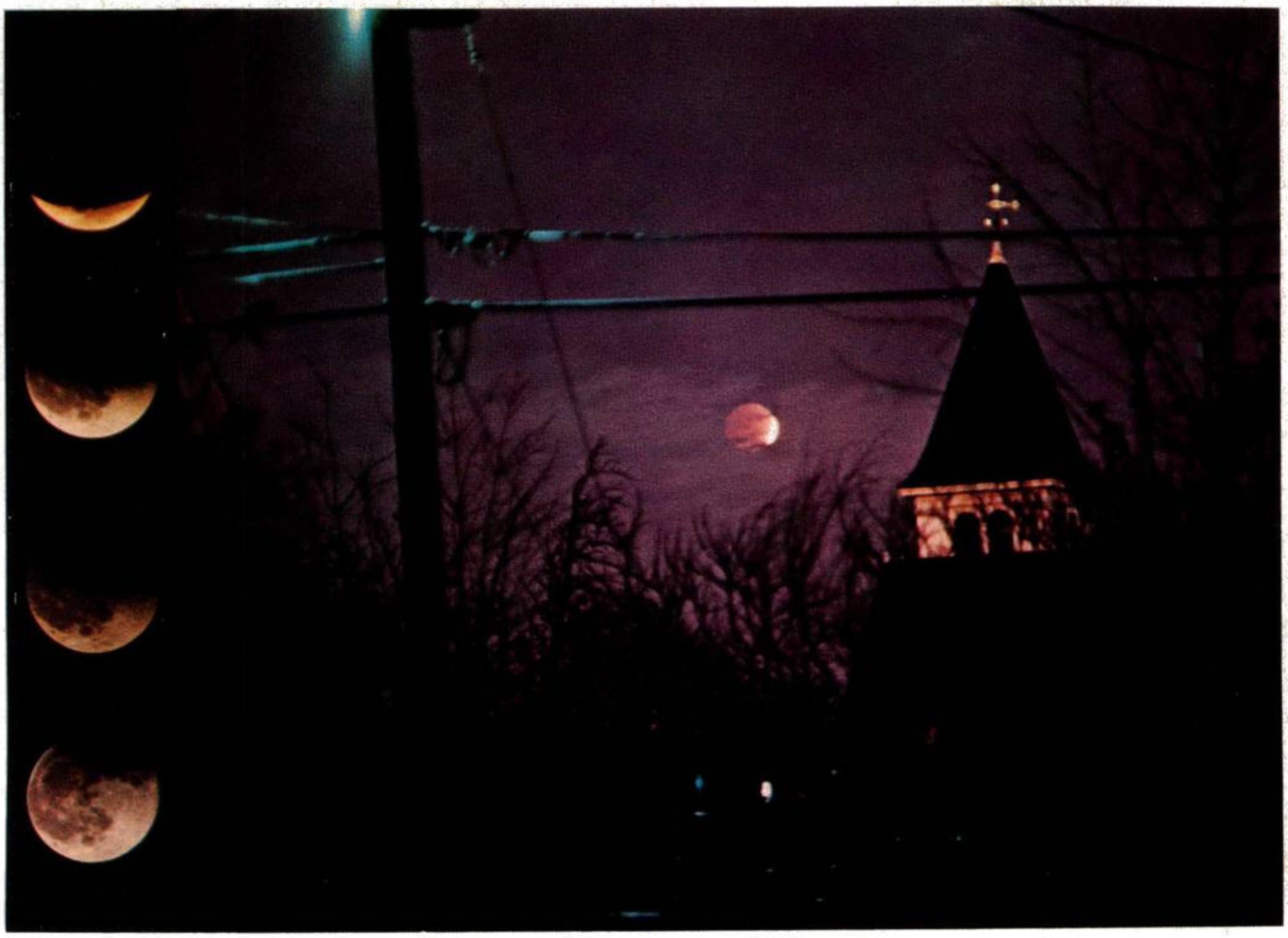
Because asteroids (including Juno) move fairly swiftly across the sky, their positions change from one night to the next. You can perceive this motion readily through photography. The piggyback method (camera mounted on the telescope tube for guided exposures) is probably your best bet; a 135mm lens will give you a fairly wide field of view. An exposure of five minutes will show an asteroid of Juno's magnitude as a starlike point. Juno is close enough to Earth that even a 24 hour interval between photos will reveal its motion. Over a longer period of time, you can build up an entire gallery of pictures illustrating Juno's rapid course through the sky.

Uranus

March is the month to start observing the planet Uranus. It rises about 10 p.m. in the beginning of the month as it approaches opposition, which will occur this year on April 25. During most of 1976, Uranus will be located in Virgo, close to the border of Libra (see the map on page 39); it will move into the latter constellation this autumn, ending a sojourn

In the dramatic photograph at far right, the brightly lit towers of New York reach toward the eclipsed moon as it rises over the city. The brightness of the sky is due partially to twilight, but mostly to the millions of lights in the city below. The six second exposure on Kodachrome-64 was taken from the 86th floor of the Empire State Building. The sequential photos were obtained through darker skies over Maine. The moon, totally eclipsed at top, creeps from Earth's shadow over a two hour period. All photos were taken through a homemade six inch f/7 reflector on Kodachrome-64; exposure times range from 30 seconds at totality to 1/250 second at eclipse end. Right: Photograph by Glenn Schneider; Left: Photographs by L.H. Price.





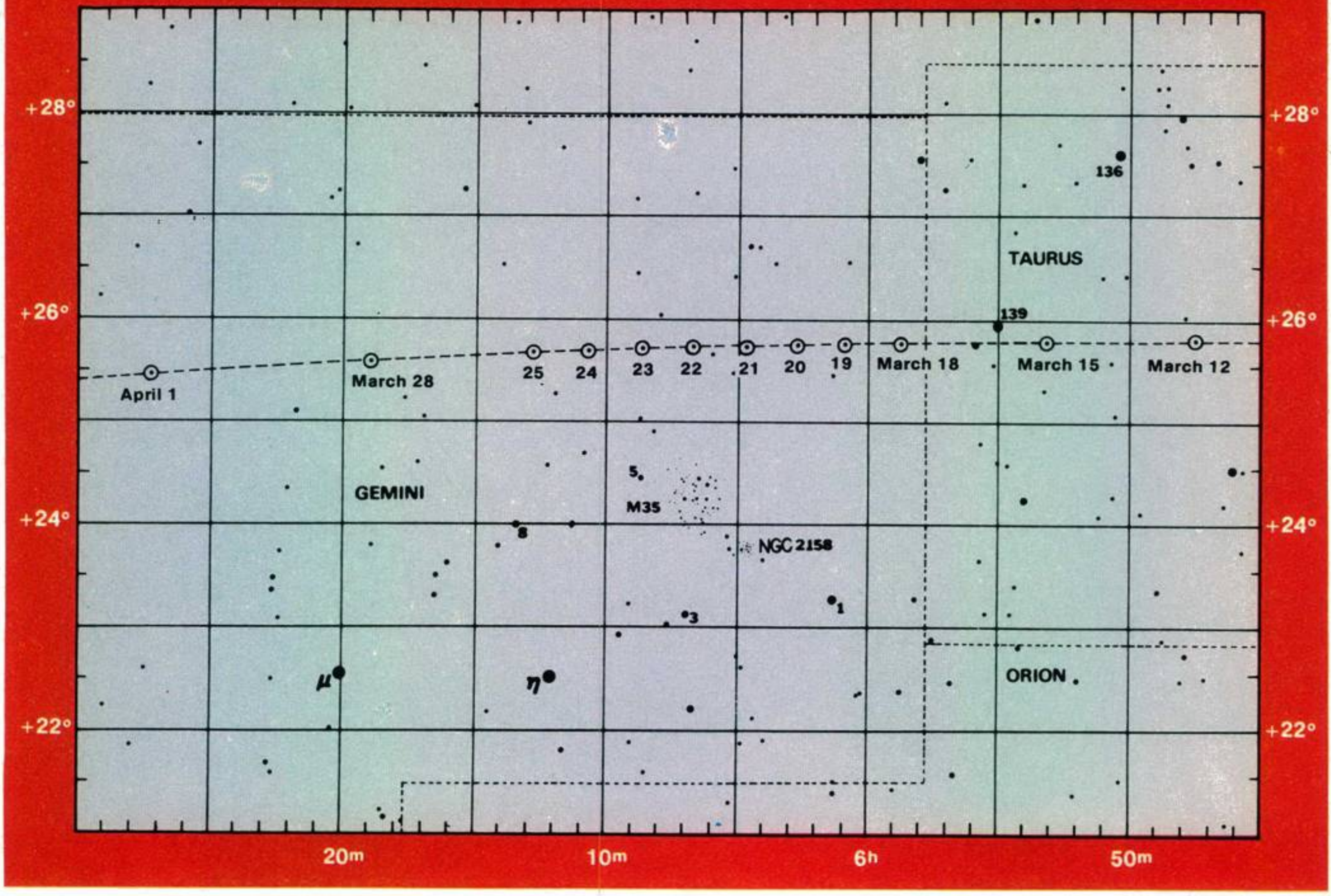
The total lunar eclipse of Nov. 18, 1975, could be seen over most of the eastern United States, providing an exciting subject for many photographers. Three panoramic shots on the opposite page illustrate different views of the moon from various parts of the country. The moon rising over New York is seen from the roof of an apartment building in a photo obtained as part of a school project; the 20 second exposure was made on Kodak Ektachrome-X through a 50mm f/2 lens. The dome in the photo below it is that of Palos Observatory in Palos Park, Ill.; the partially eclipsed moon is visible through the twilight in a four second exposure. At bottom, the moon shines in an intensely blue sky over the lights of Morganton, N.C., in a 10 second exposure. The moon is seen in more detail in the photographs at near left. The top photo is a prime focus shot taken immediately following totality's end through a Criterion RV-6. The film was High Speed Ektachrome pushed to ASA 400. A 2.4 inch Jason/Empire refractor was used for the photo below it, taken just as the moon began leaving the umbra. Exposure time is 40 seconds, also on High Speed Ektachrome pushed to ASA 400. In the next photo, Tycho and its rays can be seen just above the brighter portion of the moon's disk. A Criterion six inch Dynascope was used for the six second exposure on GAF 500 film. At bottom, the moon has moved halfway out of the umbra in a prime focus shot taken through a Dynamax 8. This print was made from Kodacolor II film. In the sequence above, a Sears 2.4 inch refractor at first focus (f/12) captured the moon at various stages of its emergence from Earth's shadow. The film used was GAF 500; exposure times ranged from 1/8 to 1/60 second. Finally, the moon rose through horizon haze on the east coast a few minutes before totality began. A 135mm lens at f/2.8 took the four second exposure on Kodachrome-64. Opposite page: Left, top to bottom: Photographs by Andrew Graves; Gerald Kisiel and Dick Sokoloff; Guy Tanzer; Right, top to bottom: Photographs by Allen A. Brunk; Joseph Peselli and Ken Benton; John M. Zupko; R.W. Lynch. Above Left: Photographs by Clifford Radziewicz; Right: Photograph by L.H. Price.

in Virgo that has lasted nearly 10 years. Because Uranus is so far from the sun (its average distance is 1.8 billion miles), it takes the planet 84 years to complete one orbit. Uranus thus spends larger amounts of time in each zodiacal constellation than the nearer planets.

Uranus is sixth magnitude, thus technically visible with the naked eye. You'll probably need binoculars to distinguish it from the stars in its vicinity. Binoculars reveal a starlike object and no more; but even a 2.4 inch refractor shows Uranus' tiny disk, about four seconds of arc in diameter at opposition. Your first look at the planet is apt to startle you, for nothing else in the sky has the same green color — not even Neptune which, although very similar to Uranus, is farther away and not as bright.

Uranus' magnitude at opposition is usually 5.7, but its brightness slowly varies — not so much that the casual observer will notice, but enough to fluctuate by about .3 magnitude. The reason is the inclination of Uranus' axis to its orbit — an incredible 98 degrees (compare Earth's 23 degree slant or Jupiter's inclination of a mere three degrees). Owing to this large tilt, Uranus sometimes presents its equatorial region and sometimes its polar area to our view. Since, like all the gas giants, Uranus is considerably flattened at the poles, its disk is larger

Mars Passes M-35



As Mars moves from Taurus and through Gemini during March, it will pass not far from the open cluster M-35. The positions of Mars are given in the map above for several days on either side of closest approach, which occurs on March 22. The passage of the planet near M-35 and its smaller companion, NGC-2158, makes an excellent long-term photography project. A night-to-night sequence of photos can vividly illustrate the motion of Mars across the sky as it nears, and then leaves, the lovely cluster. By April 1, Mars will have traveled a good distance away, nearing Epsilon Geminorum (not shown) for occultation on April 7. Map by Victor Costanzo.

when we see it pole-on, and its magnitude increases. At present, Uranus is about halfway between the two extremes. In 1964, the equatorial region was visible; by 1985, we will be looking into the pole again. Note that these changes are only apparent ones that depend on Earth's and Uranus' orbital positions relative to each other.

As with most celestial objects, Uranus looks dimmer under high magnification. So if you own a small telescope, you won't be able to distinguish surface markings by using the scope at its "power" limit. What you will see, of course, is the planet's disk shape and green color, both of which you'll more greatly enjoy at medium magnifications. Wider apertures show a little more, but even a 12 inch reflector is insufficient to show the kind of detail visible on Jupiter and Saturn.

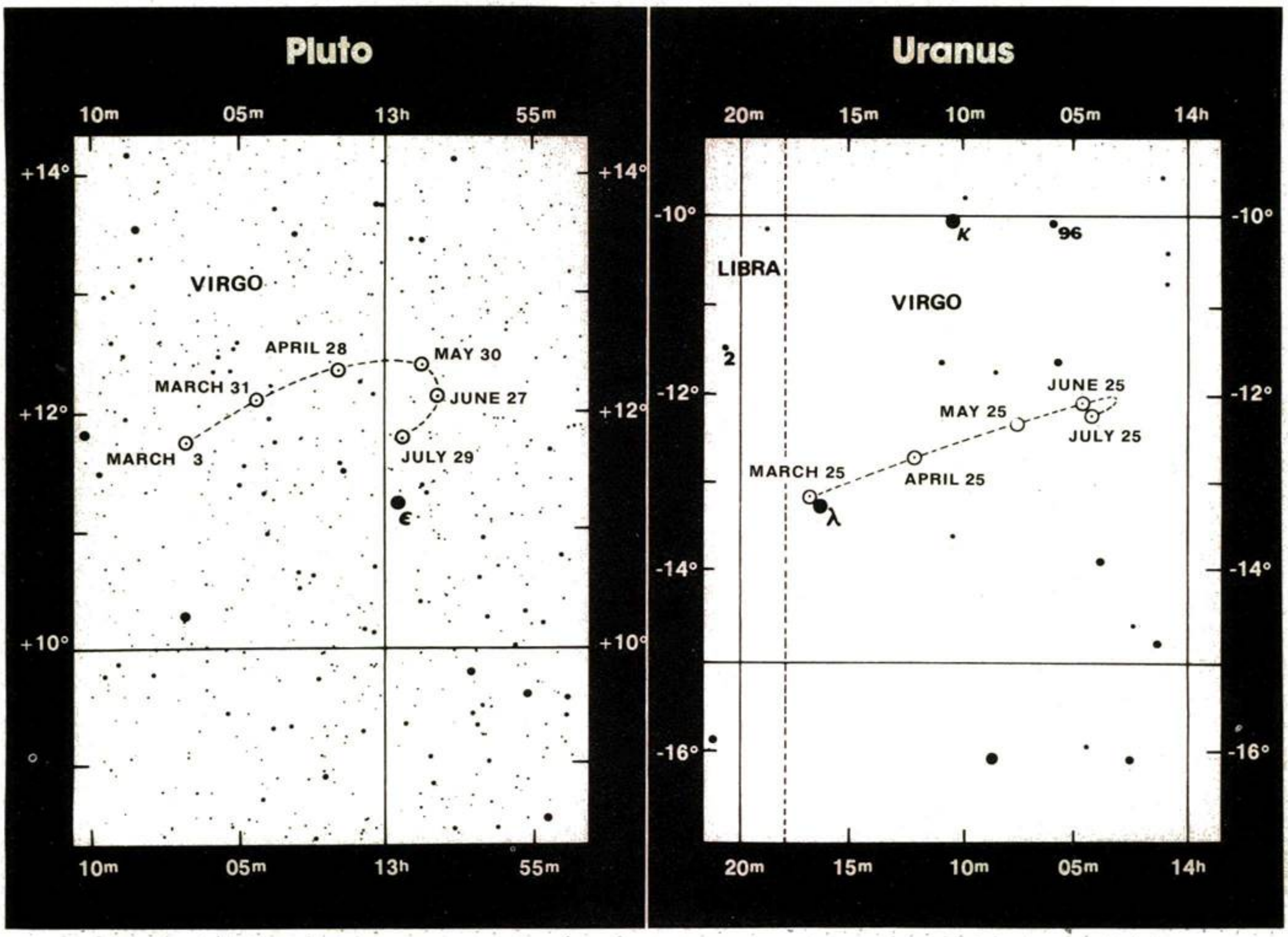
If your telescope is big enough, why not try for a look at some of Uranus' moons? There are five: Ariel, Umbriel, Titania, Oberon and Miranda. The first two are close to the planet and hard to see, and the last is so small it has only been detected photographically. But an eight inch aperture is sufficient for Titania and Oberon (the two largest moons) if you're sharp-eyed. At best, both moons are only magnitude 14!

Pluto

Uranus may be far away, but it's practically a next-door neighbor compared to Pluto. This tiny, remote planet, in opposition on March 31, will be 2.76 billion miles from Earth on that date.

Pluto's appearance at opposition is getting better every year as the planet slowly approaches perihelion in 1989. This doesn't make much difference with the other planets, as the orbits of most of them are nearly circular, and only Mars' appearance changes significantly from perihelion to aphelion. But Pluto has a messy orbit that brings it within 2.8 billion miles of the sun at its closest approach, and out to a distance of 4.6 billion miles at aphelion. This eccentric path carries Pluto closer to the sun, for several years on either side of its perihelion date, than Neptune ever comes. During those years, Pluto is the second most distant planet as it sneaks within the orbit of Neptune.

But on the average, Pluto is the farthest planet and therefore the slowest, taking 248 years for one



Stars down to magnitude 13 are plotted on the locator map of Pluto, above left. Pluto itself is only a 14th magnitude object; it is visible only in large instruments and will require careful search. Opposition occurs on March 31; Pluto's nearness to Epsilon Virginis may make it easier to find. Also in Virgo during 1976 is the planet Uranus, which reaches opposition on April 25. During the last days of March, Uranus can be found quite close to Lambda Virginis. Uranus, at magnitude 5.7, is much easier to find than Pluto; it is visible in binoculars. The map, above right, gives its positions at monthly intervals during the spring and summer, and shows stars as faint as magnitude seven. Maps by Victor Costanzo.

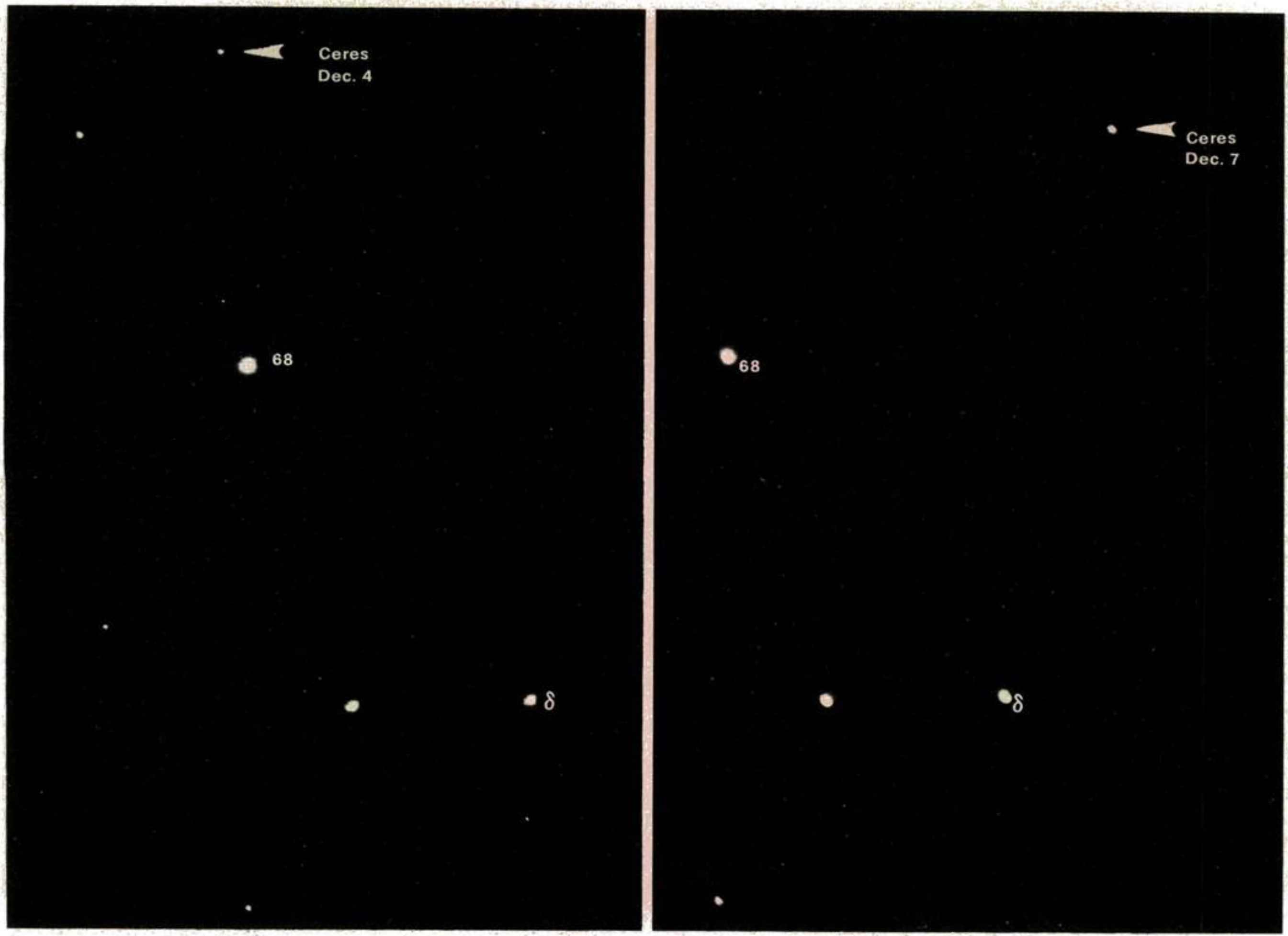
trip around the sun. It moves only about 1-1/2 degrees per year through the sky, and has covered less than 1/5 of its orbit since its discovery in 1930.

Another orbital eccentricity that Pluto has is its drastic inclination to the ecliptic — 17 degrees. No other planet travels such a slanted path. Pluto wanders away from the zodiac as if it has forgotten the road; until recently it could be found in Coma Berenices, but has since moved into Virgo. On March 31, Pluto will be located about 1-1/2 degrees from third magnitude Epsilon Virginis; it will approach that star even more closely later this year (see map, above).

Although Pluto is in a better position for observing these years, you'd never know it from the planet's brightness. "Dimness" is a more correct word, for Pluto's magnitude at opposition is only 14. You must have at least an eight inch telescope to see it; even then, an exceptionally clear night is a must, for Pluto is only marginally visible in this aperture. Larger instruments will not provide much more help; you have to know exactly where to look to know just which starlike dot is the planet.

If you really want to find Pluto, you'll have your best chance with photography. A good rule to follow for exposure time is: the longer, the better. Pluto is so dim that, even through an eight inch reflector, your minimum exposure should probably be no less than 20 minutes. There is no real lower limit to the necessary telescope size; even a 2.4 inch refractor could pick up Pluto's image if you want to spend about an hour guiding the telescope. But larger apertures, with their greater light gathering power, can cut down on the exposure time needed.

At opposition, Pluto's close approach to Epsilon Virginis will make that star an excellent guidestar for long exposure, guided piggyback photos, recording the planet's motion. A telephoto lens with a focal length of 200mm or more is powerful enough to photograph the planet, and the field will include both Epsilon and Pluto. The planet is too distant and slow moving, however, to change its position as rapidly as Juno does, and you should wait at least a week between photos. Be sure to photograph the area more than once per night to definitely distinguish Pluto's image from flaws or clumps or grain in the film.



Pluto is so small and far away that observation of surface detail is out of the question. About the only thing Pluto-hunting provides, in the long run, is the satisfaction of finally having seen the elusive little body.

Mars

Having passed its biennial opposition last December, Mars is speeding away from Earth and will not present as good a view until early 1978. Its magnitude this month falls from +0.5 to +1.1 (it becomes dimmer than Aldebaran not far away), and its diameter shrinks from 8.5 to 6.7 seconds of arc. Mars passes into Gemini in the middle of the month.

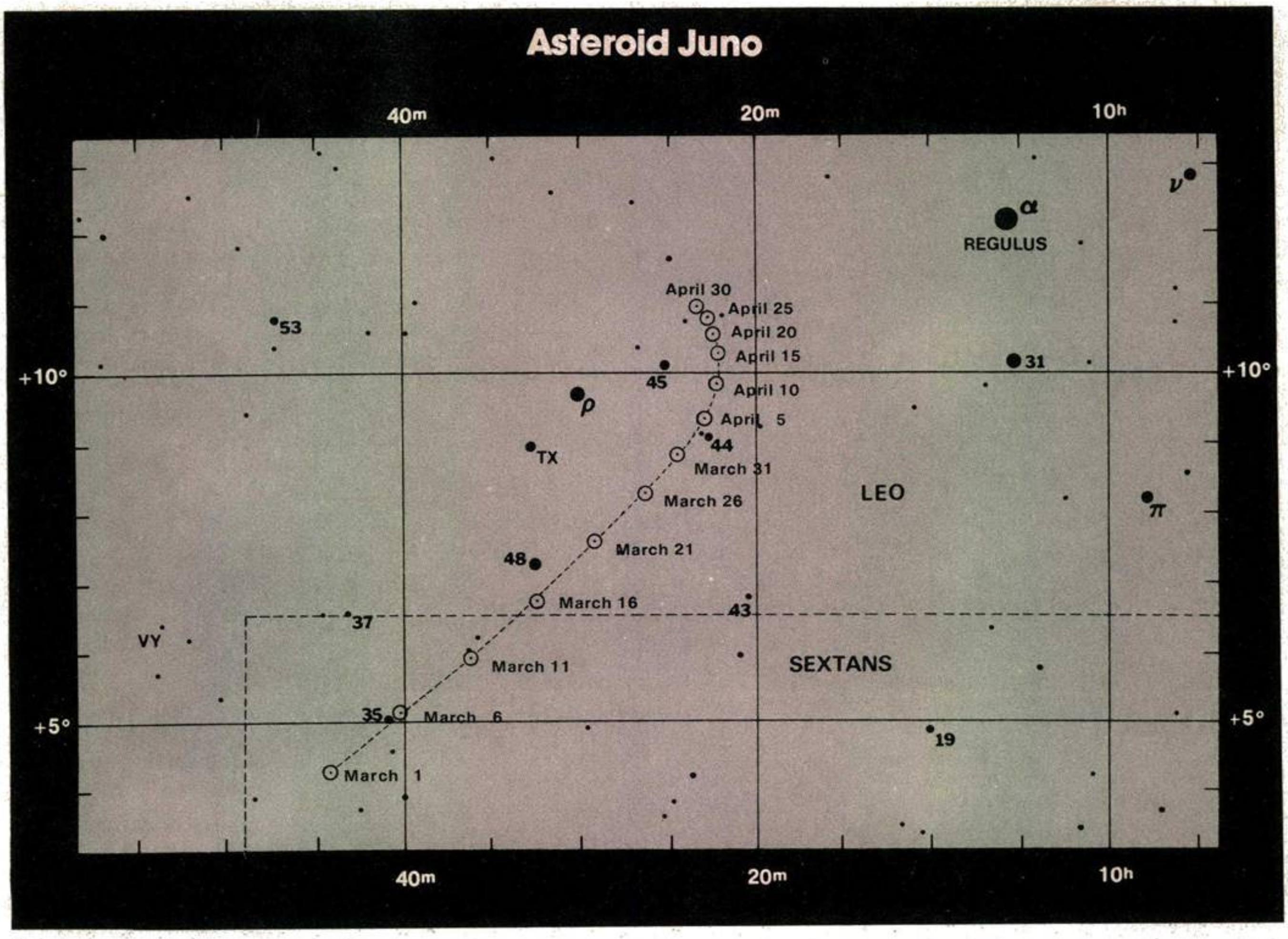
For a few days in the latter part of March, Mars will closely approach the open cluster M-35. The minimum separation of the two will be less than two degrees on March 22, as shown on the accompanying map. This "flyby" will provide an excellent long-term project for piggyback photography. You can obtain a series of night-to-night photographs showing Mars' approach and withdrawal from the cluster with a 135mm telephoto lens, mounted on your telescope tube and guided with slow motion controls. A lens of this size can partly resolve M-35 into its component stars.

Your field of view with a 135mm lens is approximately 10 x 15 degrees, so you can begin your series of photos as early as March 18 when Mars is still about six degrees from the cluster. If you center your field on the same point each night, your photo sequence will give dramatic results as Mars drifts past the nearby star swarm. The most desirable exposure, on ASA 100 color transparency film, is 15 to 20 minutes at f/2.8.

For Mars' closest approach, a larger lens or a rich field telescope is the order of the day. A 400 to 600mm focal length is ideal; it will resolve not only M-35, but also NGC-2158, the smaller cluster nearby. Your end result could be similar to the photo on page 42 of ASTRONOMY's January 1976 issue.

Early next month, observers in the eastern part of North America will enjoy a rare spectacle: the occultation of a bright star by a planet. On April 7, Mars will pass before third magnitude Epsilon Geminorum, the exact duration of the occultation will vary, depending on latitude, but should begin near 7:57 p.m. EST on the east coast, with mideclipse occurring at about 8:00. In the midwest, it will start about 6:56 p.m. CST, with mideclipse two minutes later. The occultation will be central for observers around 38 degrees north latitude (the latitude of St. Louis and Washington, D.C.).

This uncommon event will be invisible west of longitude 100 degrees, as it occurs there before sunset. Throughout an area 15 degrees east of that line, the occultation will take place during twilight;



The photographs on the opposite page of Ceres (indicated by arrows), the largest of the minor planets, were taken as it moved through the Hyades in early December 1975. The brightest star in each picture is fourth magnitude 68 Tauri (compare with the map on page 39, December 1975). These pictures are excellent examples of asteroid photography. Ceres' motion is clearly visible against the star background. Both are five second exposures on Tri-X film. An opportunity for similar photographs is provided this month by the asteroid Juno, which reaches opposition on March 1. Its course through the constellations Sextans and Leo is plotted on the map above, which contains stars down to magnitude nine. As with the Ceres photos, the motion of Juno can be easily captured on film in exposures taken at intervals of several days. Photographs by Danny Sagstetter; Map by Victor Costanzo.

if you live in this area, you may need optical aid if you want to watch. East coast observers, however, should have a good view.

Venus

At magnitude -3.3, Venus glows radiantly in the east before dawn. You won't see the planet against a completely dark sky because it rises only about an hour before the sun this month, but Venus' brilliance is enhanced as the stars fade in the twilight and it shines alone. Venus is moving away from Earth and closing in on the sun, gradually rising later in the morning as it approaches superior conjunction in June. Through the telescope, the planet is a tiny, nearly full circle; 94 percent of its visible disk is illuminated at month's end.

Jupiter

Jupiter is headed toward conjunction with the sun, and it is dropping low in the west during March evenings. The giant planet moves from Pisces into Aries on the first day of spring, becoming the brightest object in the latter constellation at magnitude -1.6. At the beginning of the month Jupiter is 524 million miles from Earth, and this distance increases to 548 million miles by the 31st.

Saturn

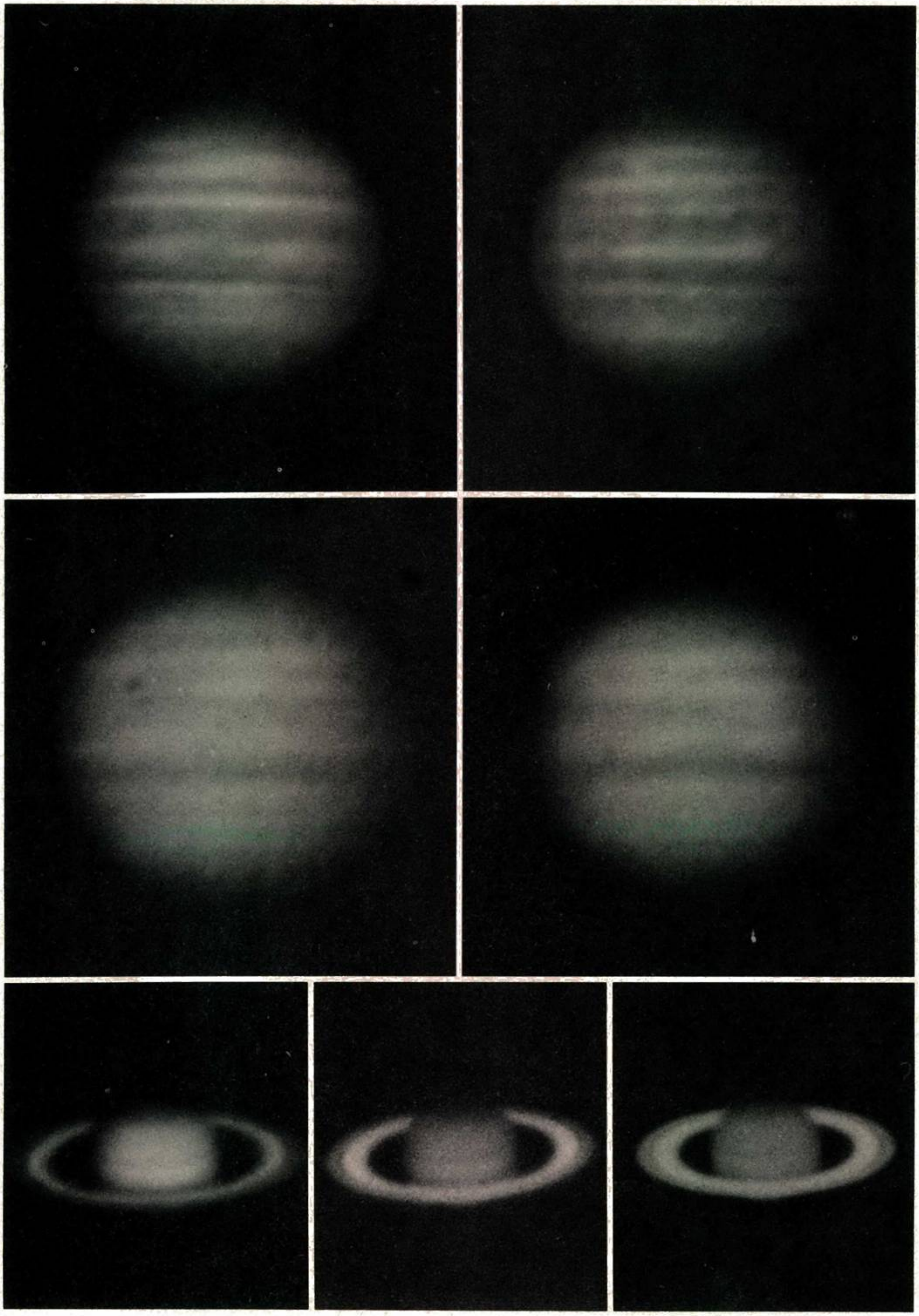
Saturn is near the zenith at sunset during March, located in Gemini, near the border of Cancer. Because it, too, is headed away from Earth (it moves from 775 to 815 million miles from Earth this month), its magnitude decreases from +0.1 to +0.3 — still bright enough, though, to outshine all Gemini's stars, including Castor and Pollux. Saturn is well placed for telescopic observation throughout the month.

Neptune

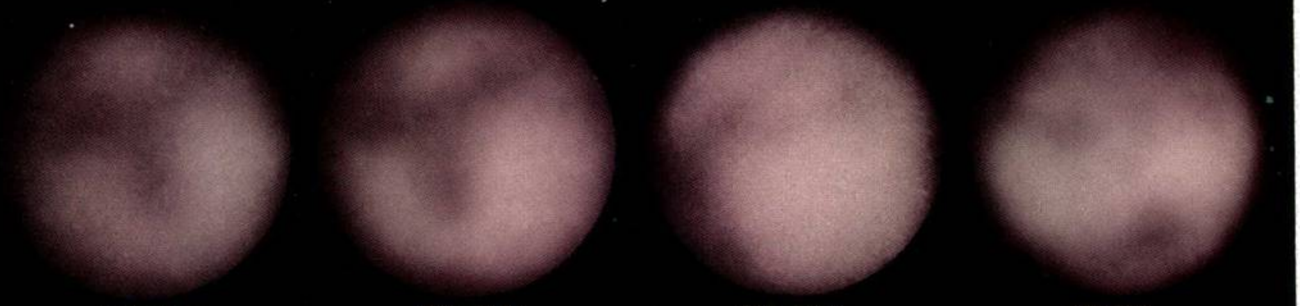
The remaining outer planet, situated in the southern part of Ophiuchus during 1976, rises about 1 a.m. this month. Neptune will reach opposition in June and will be more easily seen at that time; its locator map will appear in an upcoming issue.

Lunar Eclipse Observations

March nights will provide observers with ample



Mars Rotation Dec. 7-8, 1975 EST



CM: 290°
7:45 p.m.

CM: 310°
9:30 p.m.

CM: 330°
11:30 p.m.

CM: 20°
1:00 a.m.

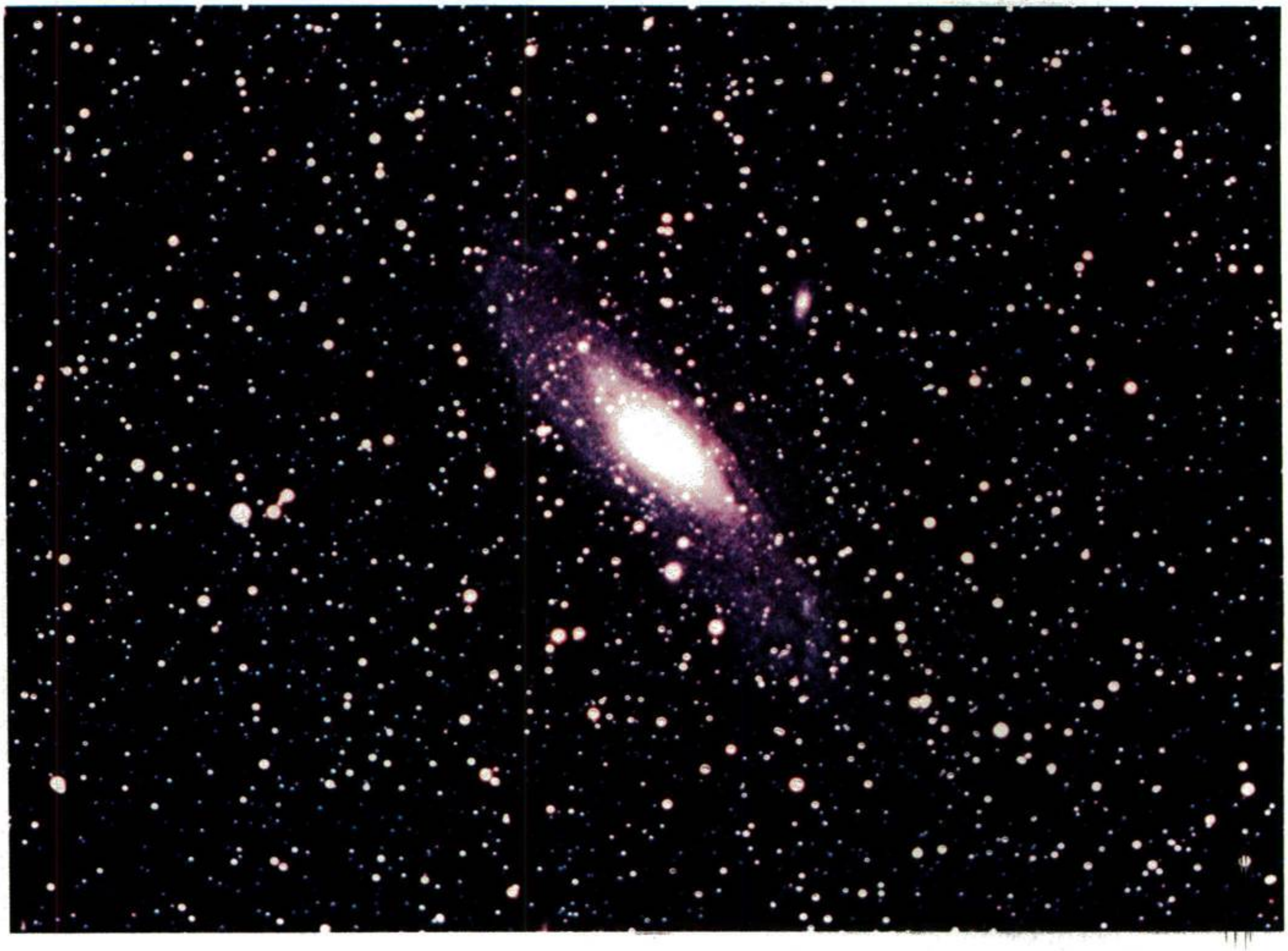
Mars' rotation period is about 24-1/2 hours — only slightly longer than Earth's. A single night's observation will reveal the motion of the planet about its axis, as the dark markings travel across its visible disk. Mars' nearness to Earth at opposition brings its geography into great prominence, making possible such photo sequences as that reproduced above. The photographs, obtained a week before opposition, were taken with the afocal system; an eight inch f/5 reflector was used with a 10mm eyepiece. The 250mm lens used on the camera gave an effective focal length of 1,006 inches (f/126). Martian detail is subtle and easily lost, and care should be taken to keep instrument vibration down to a minimum. In this case, the camera was mounted on a separate tripod. The unfiltered exposures of 1-1/2 to 2 seconds were made on Kodak SO-410 film. Photographs by Lester F. Yuill.

Many of the planets were at their nearest and brightest toward the end of 1975, and excellent photographs could be obtained of them. In the photograph of Jupiter at top left, taken on Oct. 25, the cloud bands — particularly those in the equatorial region — are startlingly clear. Even more detail is revealed in the picture at top right: Jupiter's turbulent atmosphere has produced a large spot in the temperate zone, and other spots appear to be in the process of formation. This second photograph was taken on Nov. 6. Each picture is a seven second exposure obtained through a homemade eight inch f/7 reflector, working at f/80. High Contrast Copy film was used. The two Jupiter photographs in center were taken within a half hour of each other on the same night with similar equipment: an eight inch Coulter Newtonian reflector and H&W Control film. The two second exposure at left center includes the shadow of Io. At right center, Jupiter is seen in a three second exposure, and Io's shadow has left the disk. Subtle differences can be detected between the two photos. The ringed planet Saturn reached opposition in January 1976. Opposition is the best time to photograph any of the superior planets, since they are at their closest to Earth at that time. But good pictures can be obtained for months on either side of this date. The photograph at bottom left was taken a month before Saturn's opposition — on Dec. 17. Delicate shadings on the planet's cloud surface can be detected — especially one notable equatorial band. The difference in brightness between the rings is pronounced. This seven second exposure on SO-410 film was taken through an eight inch f/7 reflector. Earlier this year, on Jan. 19, the photo at bottom center was obtained. A two second exposure on Tri-X was made using the afocal system. Because Saturn is more distant than Jupiter, its surface appearance does not change nearly as much — as shown by the picture at bottom right, taken later the same night. Tri-X film was used for this one second exposure developed in Acufine. Top: Photographs by James K. Rouse. Center left: Photograph by Lester F. Yuill; Right: Photograph by Bob Kimmel. Bottom, left to right: Photograph by James K. Rouse; Photograph by Lester F. Yuill; Photograph by Bob Kimmel.

opportunity to test both their visual skills and equipment capabilities. But our readers have not been idle during the past few months, as demonstrated by the volume of reports and photographs received by ASTRONOMY. The following includes some of the best.

The total lunar eclipse of Nov. 18, 1975 was visible in the eastern United States. Observers in Europe saw the entire event, but in the western hemisphere the eclipse was already in progress at moonrise, and spectators had to be content with its last stages. Residents of eastern coastal areas were able to watch all of totality, provided the horizon was clear. Other observers witnessed only the end of totality and the moon's emergence from the umbra. Depending on their longitude, some missed the total phase completely.

Most of those who judged the eclipse's darkness on the Danjon scale — which rates an eclipse from 0 (dimmest) to 4 (brightest) — assigned a value of 2; some thought it was 2.5, and only a few rated the eclipse at 3. In fact, the eclipse was not a dark one, as European observers (who had a better view) have attested. The moon did not pass through the center of the umbra, and its surface could not darken as thoroughly as it has during other eclipses. Since the eclipse could only be seen near the horizon in the U.S., ground haze may have dimmed the moon to



The Andromeda galaxy (M-31) is seen here through a rich screen of intervening stars. The nearest large galaxy to our own, it is at its highest in November, when this photograph was taken. Some of the structure in its massive spiral arms can be detected; the spiral sections are less condensed and less bright than the nucleus, and fairly long exposures are needed to reveal their form. M-31's two small companion galaxies, M-32 and NGC-205, are also seen here. This 10 minute exposure on Fujichrome R-100 film was taken with a 5-1/2 inch Schmidt camera at f/1.65. Photograph by John Sanford.

a greater extent than can be accounted for by Earth's shadow alone.

Most areas enjoyed good weather conditions, unlike those that prevailed during the May 24 eclipse. However, several observers on the coast had to wait for the moon to rise above low lying clouds. L. H. Price of Kettery, Maine, reports that "clouds near the eastern horizon interfered with observation until well after second contact" (entrance into the umbra). After clearing the cloud cover, "the eclipse appeared bright, but at mideclipse stars of magnitude five and the outline of the Milky Way in Cygnus were visible."

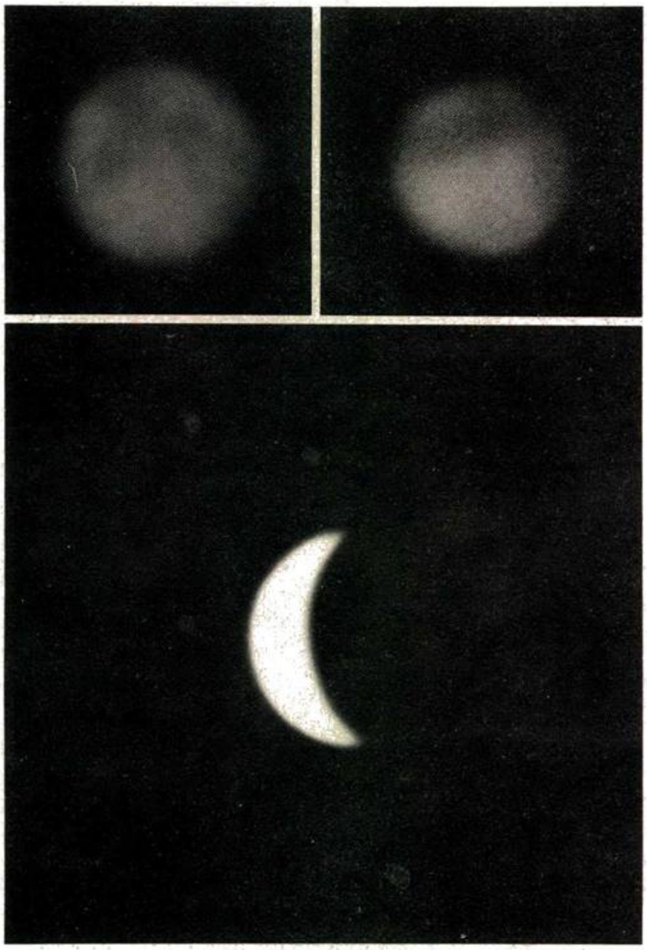
Caption for pages 44 and 45

Superb photographs of two of the most spectacular objects in the sky are reproduced on the preceding pages. Both are located in the constellation Orion, and both require long exposures to disclose their full detail. The Horsehead nebula is located just south of Zeta Orionis, one of the stars of the belt; the Horsehead is part of a cloud of thick dust hiding the brighter nebulosity behind it. Zeta is the brightest star in this photo, and more diffuse nebula can be seen near it. A home built six inch reflector took the 90 minute exposure on Fujichrome R-100 film; according to the photographer, seeing was poor! The Orion nebula (M-42), found a few degrees south of the Horsehead is an incubator of new, young stars; it shines by reflection from these hot stars. The Trapezium, a group of four stars at its center, can be seen visually but is blotted out in most photos. Very long exposure photographs of the entire constellation show it wrapped in nebulosity — the greatest concentration of which is located here. This is a one hour exposure on Fujichrome R-100 film. Photographs by Brad Wallis.

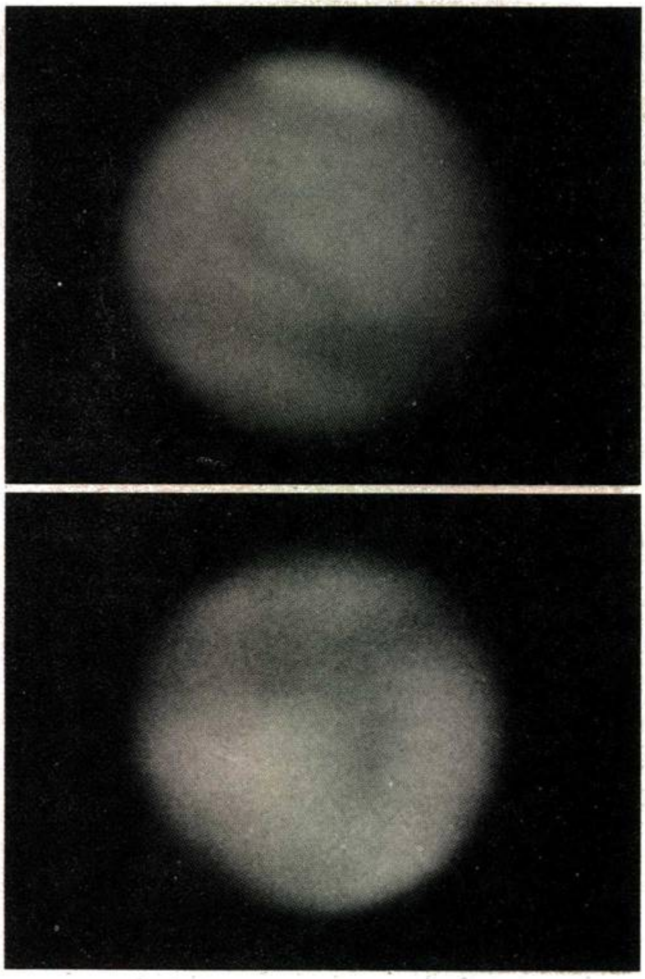
Farther southwest in New York City, the moon rose above the clouds just before totality began — as reported by Glenn Schneider of the Amateur Observers' Society, who viewed the eclipse from the 86th floor observation deck of the Empire State Building. Other members of the Society assisted in a public observation at the Hall of Science Planetarium. Schneider writes that the eclipse was so bright "many local residents who turned out for the eclipse-watch could not be convinced that the eclipse was total." Other coastal observers feared they would be "clouded out" by banking clouds on the horizon, but in most cases the weather remained fair. An interesting note from John M. Zupko of Trenton, N.J. states that "this eclipse started where the one in May left off" — meaning that clouds had obscured the earlier eclipse just before the exact phase visible at moonrise in November.

The moon was already totally eclipsed as it rose at sites farther west. In Dover, Ohio, Brent Archinal first sighted “the almost invisible totally eclipsed moon... approximately five degrees above the horizon at 5:35 p.m. (EST). It appeared as a thin ghostlike crescent moon with no well-defined terminator.” As totality ended, “dark fuzzy projections and hazy black wisps could be seen extending out from the umbra, so the border between the penumbra and umbra was by no means distinct.” Richard and Dolores Hill of Midland, Mich. reported seeing two satellites “vanish into the same shadow that covered the moon.”

Douglas Smith at Oakland University in Michigan describes the reappearance of the moon from shadow as follows: “First, a lone mountain peak on the limb turned from the characteristic copper of the totally eclipsed moon to orange, yellow and finally white. This took almost 20 seconds. Then a crescent of orange spread from the base of the peak and slowly turned white as it advanced across the disk.”



These two pictures of Mars, both taken on Dec. 21, 1975, demonstrate the different results obtained with different equipment and development techniques. The photograph at left is a three second exposure on High Contrast Copy film, taken through an eight inch Optical Craftsman reflector at f/77. It was developed in H&W 4.5 for 12 minutes at 68 degrees Fahrenheit. The picture at right, taken just a few hours later, shows a different central meridian. A Celestron 8 at f/98 obtained this one second exposure on Plus-X film. This was developed for seven minutes in Microdol-X (1:1) at 68 degrees Fahrenheit. Crescent Venus was photographed on Sept. 28, 1975; the 1/4 second exposure on Plus-X was taken through a Celestron 8 at f/77. Photographs by Steve Reed.



Two photographs of the planet Mars, taken near its opposition date last December, show an apparent shrinking of the polar cap over a period of 10 days. However, the cap in the upper picture may be an effect caused by haze in the Martian atmosphere. In this picture, obtained on Dec. 7, 1975, dark surface markings are visible below the cap. D-19 developer is responsible for the slight gibbous appearance of the disk in this five second exposure printed on low contrast paper. By Dec. 17, when the bottom photograph was taken, other surface details can be seen. Exposure time was again five seconds, and the High Contrast Copy film was processed in a 9:1 mixture of H&W Control and D-19. Both of these Mars photographs were taken through a homemade eight inch f/7 Newtonian reflector working at f/105. Photographs by James K. Rouse.

Ceres

The minor planet Ceres was in opposition on Dec. 1, 1975. Several photographers captured the asteroid’s image on film, and two photographs by an enterprising young reader, Danny Sagstetter, demonstrate its motion against the background of the Hyades (see page 40).

Asteroid photographs are always in short supply at ASTRONOMY. If you’d like to help rectify the situation, this month’s opposition of Juno provides a good opportunity. Both color and black and white shots are acceptable, and photo sequences showing the asteroid’s change of position are particularly welcome.

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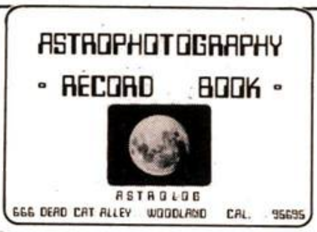
continued on page 64



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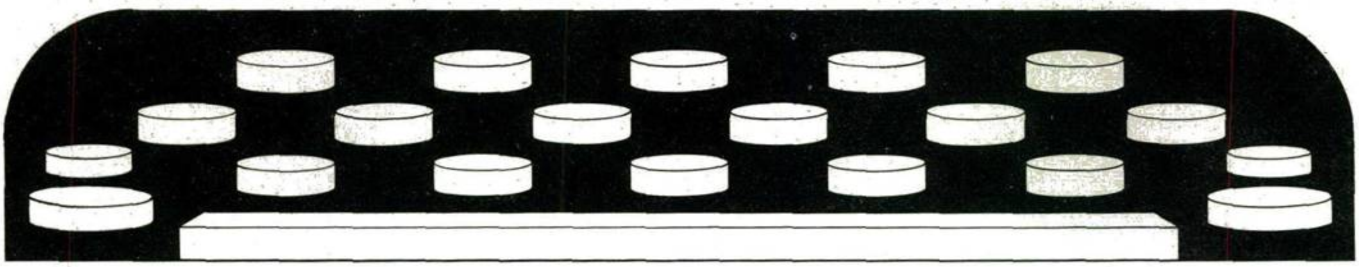


IN FOCUS

What's After Tune Up Your Telescope?

Sir / The Equipment Atlas article, "Tune Up Your Telescope" by Thomas C. Bretl (December 1975), was not only interesting but very helpful.

As a member of the San Francisco Amateur Astronomers, Inc., I know that most youngsters are stumped when they have to collimate their new Newtonian telescopes. Your article can help them, and give them much encouragement as well.

We would appreciate it if you could tell us whether we can look forward to other such instructive articles in the future?

ARMANDO ZUCCHI
San Francisco, Calif.

Mr. Zucchi / Indeed you may!

Starspots Cast Shadows of Doubt

Sir / I read the interesting article entitled "Starspots on Betelgeuse" (October '75). However, computer enhanced pictures leave me with shadows of doubt. How can we be sure that what the computer is enhancing is really there and not just a human interpretation of something we might not be able to recognize? Some further information on the Interactive Picture Processing System would be welcome.

SALLY TESTA
Cedar Grove, N.J.

Mrs. Testa / In obtaining information about Betelgeuse, three Kitt Peak National Observatory scientists photographed the star using the 158 inch Mayall telescope. An image intensifier was coupled to the telescope to help obtain detailed photographs of the far-off star, and several short exposure photographs were obtained to eliminate fuzziness produced by Earth's turbulent atmosphere.

The actual photographs themselves were reduced to magnetic data by our CDC 6600 computer, thus eliminating any human interpretation. This magnetic tape was then "fed" to our Interactive Picture Processing System which was "told" to accentuate any details in the image. The spectacular result, of course, was well represented in the pages and cover of ASTRONOMY.

You might be further interested to know that Betelgeuse data was obtained on four separate evenings, and that all data was compared in determining the results.

The three scientists, Drs. Jack Harvey, Roger Lynds, and Peter Worden, all agree that the "starspots" we see on the computer enhanced pictures are actual features on the star. According to Worden, "The regions represent huge hot and cool areas, or convection currents, similar to those seen on our own sun." Naturally, we here at Kitt Peak are quite excited about the possibilities of these new techniques and instrumentations: Perhaps we can now begin to develop quantitative data on other stars, and thus gain greater insight into stellar evolution.

DAVID L. MOORE
Director, Public Information Office
Kitt Peak National Observatory
Tucson, Ariz.

Light Pollution Woes

Sir / Celestial viewing in New York City is terrible! Most people marvel at seeing any stars in the sky — if they can see them at all. Not only do we have to contend with city lights and smog, but tall buildings everywhere block the view. Because of these facts, I never considered buying a telescope. Where was I to set it up — on a street corner? On the roof to my apartment building which is inaccessible because of a locked door? In the parks where the least that can happen is the telescope being spirited away by muggers? And traffic being what it is 24 hours a day, you cannot get up and drive to the country to view stars when you know that the drive would take hours.

Because of this and your magazine, I have turned into an armchair astronomer. Parenthetically, thanks for the "Buyers' Guide to Telescopes" (October 1975). It gave me some ideas for the future if I change my location.

In rereading your Publisher's Memo in the May 1975 issue, I see no mention of geographical breakdown of subscribers. I think this might be useful and informative to other readers — especially to those like myself who grow jealous and envious reading letters and seeing photographs taken by people who live in nice, clear regions where they can see the stars.

It's a shame that living in the city I cannot even do what Walt Whitman did:

"When I heard the learn'd astronomer,
When the proofs, the figures, were ranged in columns before me,
When I was shown the charts and diagrams to add, divide, and measure them,
When I sitting heard the astronomer where he lectured with much applause in the lecture room,
How soon unaccountable I became tired and sick,
Till rising and gliding out I wander'd off by myself,
In the mystical moist night-air, and from time to time,
Look'd up in perfect silence at the stars."

All I can do is look up in livid rage at the glare and smog.

AARON ISQUITH
Brooklyn, N.Y.

Sir / In the October 1975 issue in an article entitled "Aurora", you published a picture of the United States taken at night showing lights from all the cities. This was stated to be an Air Force weather satellite composite picture.

This is the most horrifying picture I have ever seen from the standpoint of what is happening to observational astronomy.

CHARLES W. FINNIGAN
Maitland, Fla.

To All City Dwellers / How many ASTRONOMY readers live in big cities or brightly lit suburban areas, and how do you cope with the sky fogging problems of light pollution? And what about sky photography — we seldom receive astrophotographs from city dwellers even though planetary conjunctions and the like are unaffected by city lights, and are perhaps more interesting with a skyline (witness the photograph on page 35 this month). Since we are thinking of writing a Gazer's Gazette and Photography in

Astronomy on light pollution and its effects sometime, we would appreciate help in gathering the necessary research background for these articles.

We invite city dwellers to write to us specifying the observing and astrophotography problems you encounter due to light pollution in your area, telling us how you solve these problems. Also please send both color slides and/or black and white prints that illustrate your specific light pollution problems and (if you are so fortunate) how you solved them. Address your correspondence to Richard Berry, Technical Editor.

More on Binoculars for Stargazing

Sir / This letter is aimed at everyone who enjoys using binoculars to observe the night sky.

During the winter, the ground is not only hard but cold and uncomfortable. A beanbag chair overcomes these problems. Virtually any position can be assumed in comfort, and the chair, though bulky, is light and easily transported. It also serves to help prop and steady the arms for steadier viewing.

PHILIP GIGLIO
Monroe, La.

Sir / Your January 1976 "Binoculars for Stargazing" by James Mullaney was okay, but I think you missed something your readers should know. The age of the user is important in choosing binoculars (or a telescope). Here's why.

The light from stars collected by the objective lenses in binoculars or a telescope is focused in the form of a little image of the objective behind the eyepiece. If you look at binoculars or a telescope from behind the eyepiece you will see this little image called the *exit pupil.*

You can easily determine the size of the exit pupil by dividing into the diameter of the objective lens the magnification or power of the telescope or binoculars. For example, 7 x 50 binoculars have 50mm aperture objective lenses with magnifying power of seven times. Dividing the 50mm aperture by the magnification of 7 power tells you that the exit pupil is just slightly larger than 7mm in diameter.

Why is the size of the exit pupil so important? Because its diameter should not be larger than the pupil of your eye. Since the exit pupil is just a small picture of the objective lens, if the exit pupil of your binoculars is larger than the fully opened pupil of your eye, your eye will not collect all the available light gathering power of the objective lens.

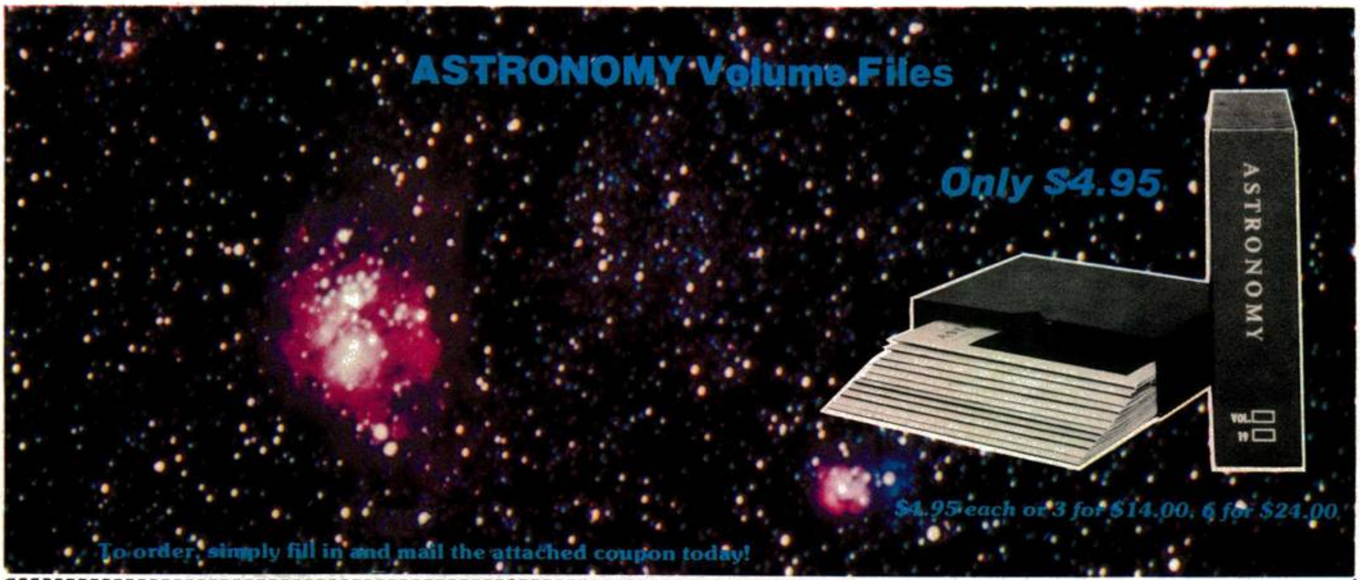
At the age of about 20, when your eyes are fully dark adapted, the pupil in your eye can open to its maximum size of 7 or 8mm in diameter. But by the time you're 35, the maximum pupil opening is reduced to 5.5 or 6mm. Consequently, if you use 7 x 50 binoculars when you're over 35, you're wasting the full light gathering benefits of these binoculars. As a matter of fact, you will still see an image, but it can't possibly be as bright as it should be because your 5.5mm pupil is only using 38mm of your 50mm aperture binocular objective lenses. For you, 10 x 50 binoculars are the better choice because the higher power reduces the exit pupil size to 5mm in diameter allowing it to fit into your eye's pupil.

Finally, at 50 to 60 years of age, your eye's pupil cannot open wider than 4 or 5mm, so you might find 15 x 60 binoculars the best choice since the 4mm diameter exit pupil matches the size of the pupil of your eye.

LESLIE GOMBAR
Detroit, Mich.

Gentlemen / Thank you for the additional suggestions and information you provided on "Binoculars for Stargazing" by James Mullaney (Equipment Atlas, January 1976).

We are sure our readers will find your comments most enlightening and are therefore pleased to publish them.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The Zeta Reticuli Incident

by

Terence Dickinson

Demand has increased daily for ASTRONOMY to reprint "The Zeta Reticuli Incident" by Terence Dickinson which documents the astronomical implications of a famous UFO incident. Since the issue in which it originally appeared — December 1974 — is now out of print, we are proud to offer the article as a full color reprint.

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ASTRO-NEWS

Latest News From the World of Astronomy

NASA Considers New Search for ET Life

NASA scientists are studying new techniques — including construction of giant radio antennas in space or on the back side of the moon — to detect radio signals from extraterrestrial civilizations. Led by Dr. John Billingham, head of the Interstellar Communications Study Group at NASA's Ames Research Center near San Francisco, the effort may be a successor to the 1971 Project Cyclops study. Billingham recently discussed these plans with colleagues at the Johnson Space Center in Houston.

No one really knows how many other civilizations are active in our galaxy. A formula known as *Drake's equation* relates factors such as planetary formation, life development, intelligence and technology advances and others to determine the probability of concurrent galactic civilizations. (See "We Are Alone," December 1975.)

According to Billingham, most factors cancel each other out and the whole equation is reduced to the assertion that "the number of intelligent coexisting galactic civilizations is about equal to the average civilization's lifetime in years." That factor is the most mysterious of all and can only be guessed at. He surmised that perhaps a million such civilizations are now spread throughout the Milky Way, with an average separation of 800 light-years.

The Cyclops study charted a project which could search for radio transmissions from such civilizations. Cyclops was not an attempt to find the best way to conduct such a search, but only to determine if any effort within human technological capabilities would be successful. Billingham was careful to distinguish between CETI, the *communication* with extraterrestrial intelligence, and SETI, the *search* for such entities.

It was impossible to assert that the Cyclops study would have been sufficient to discover extraterrestrial intelligence, Billingham cautioned. One radio dish might have been enough, or the planned 1,000 dishes might have failed. He calculated that if our galaxy held 100,000 civilizations, 700 giant dishes would have had a 2:1 chance of detecting at least one of them.

Listening at the "best" frequencies for interstellar radio still leaves searchers with about two billion radio channels per star; present day systems would take centuries to check out each star of interest. The 1,000 steerable antennas of Cyclops would take 20 minutes to investigate each star; the million interesting stars found out to 1,000 light-years from Earth (out of 11 million stars contained in such a sphere) would take 30 years to study.

What might induce a civilization to broadcast radio signals in the first place? Billingham suggested that it might be an act of hope, a missionary project or a cry for help. How could, however, an intelligent species acquire enough confidence in the existence of a listener to undertake the tremendous expense of becoming a transmitter?

Confidence in the existence of other intelligent civilizations, NASA scientists believe, could be based on a number of factors which have coalesced many times in the 10 billion year history of the galaxy. Two technological civilizations might, by pure chance, occur simultaneously within a few light-years of one another, and one might detect the other's internal signals. This could take place in a binary system, with two stars in a dense cluster, or on two planets in the same solar system.

Alternately, a civilization might find life, fossil evidence or artifacts of vanished civilizations on nearby planets, encouraging the belief that life or intelligent life is not a random freak occurrence but quite common. A civilization, making such a discovery, will be stimulated toward further exploration.

Though he couldn't specify aims at present, Billingham spoke of current efforts in progress at Ames. Although it is too early to report results, he expressed confidence and enthusiasm for the promising techniques being studied.

Project Cyclops showed that SETI was feasible; NASA is now studying means to make it practical.

Record Year For Comets

The year 1975 was a banner year for both comet discoveries and discoverers. The Smithsonian's Central Bureau for Astronomical Telegrams recorded 13 new comets last year, including six periodic comets — also a record. Japanese observer Hiroaki Mori became the first person to officially discover two comets in the same night when he sighted 1975j and 1975k on Oct. 5.

Because many observations go unreported or lack sufficient confirming data, the total for 1975 was not higher. In addition, two periodic comets known since the 19th century failed to put in scheduled appearances last year. But, as NASA's Stephen Maran pointed out during Kohoutek's disappointing visit in 1973, "comets are fickle." They change their courses, fragment or disappear completely.

Supernova Tied to Rise of Astronomy

Did a dazzlingly bright supernova in the southern hemisphere constellation Vela 10,000 years ago lead to the development of mathematics, astronomy and the need for written records?

Yes, says George Michanowsky, an amateur scholar of ancient Mesopotamian cultures and cuneiform, a writing system developed by the Sumerians. According to Michanowsky, a supernova — unknown to modern astronomers until recently — stimulated great interest in studying the sky and gave birth to legends suggesting that Vela was sacred to Ea, the Sumerian god who taught mankind the arts of civilization and was the forebearer of the mythological Prometheus.

These wisps of interstellar gas are all that visibly remain of the supernova that may have catalyzed the thoughts of Mesopotamian people 10,000 years ago, and led to the development of modern astronomy. Steward Observatory photograph.

The exact date of the supernova is unknown. All that remains today of the star is the Gum nebula, a glowing cloud of gaseous filaments covering about 10 square degrees of the sky. A radiation source — perhaps a pulsar — is found in the center.

In a recent interview in the **New York Times**, Michanowsky said there were several ancient texts that referred to a great star in the region of Vela. One such source said that it should be considered a good sign if a bright planet moved in a certain way relative to Vela.

Until the appearance of Michanowsky's theory, none of this was considered significant. When some of the Mesopotamian astromical writings were translated decades ago, no one knew of a supernova in Vela. Armed with the recent knowledge that a supernova did occur in Vela, he went back to find more evidence.

The most striking piece of evidence found, Michanowsky believes, is contained in the *Mul Apin*, a Babylonian copy made in 1000 B.C. of a much older Sumerian document. In a sequence of stellar names, he found a reference to a "giant star of the god Ea in the constellation of Vela of the god Ea." There is no especially bright star now in Vela.

In the millennia after the explosion, the Mesopotamians developed astronomy, writing and mathematics. Their culture grew into mankind's first known civilization.

Although one expert on ancient Mesopotamia has found Michanowsky's interpretations to be "scholarly" and "highly conscientious throughout", other experts of Mesopotamian history have expressed reservations about his theory. The field is generally sluggish toward accepting new ideas; it was decades between the discovery of the first clues and the final acceptance of the fact that the Sumerians even existed.

Though the supernova is now nothing but a historical fact, Michanowsky feels it should not be forgotten. "Next to the sun," he said, "it may have been the most important star in the history of mankind."

Location Chosen for 165 Inch Telescope

A volcanic peak 7,500 feet above the Atlantic Ocean in the Canary Islands will be the site of the new British Northern Hemisphere Observatory (NHO). The observatory will house three main telescopes, including a 165 inch (4.2 meter) reflector and a 39 inch (1 meter) instrument.

Less than 100 miles off the northwestern coast of Africa, the La Palma site was chosen after extensive testing. Excellent weather and air stability — vital to visual astronomical work — were better than any other site examined. Although there is a small active volcano at the southern end of the island, the pollution-free atmosphere is impaired only occasionally by Saharan dust.

The NHO will be part of the newly organized Spanish Astronmical Institute. Though a Spanish observatory, La Palma will shelter both the NHO and other instruments at the site, including a new European solar telescope.

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Cerro Tololo Telescope In Full-Time Use

The largest optical telescope in the southern hemisphere — and presently one of the three largest in the world — was officially placed into full-time operation Jan. 13, 1976.

The 158 inch (four meter) reflector at Cerro Tololo Inter-American Observatory in Chile will provide astronomers their best look yet at celestial objects clearly viewed only south of the equator.

Spectacular photographs of the brightest globular cluster, 47 Tucanae, and one of the strongest known radio sources, Centaurus A, have been obtained by the Cerro Tololo telescope (see Astro-News, January 1975).

Dr. Victor Blanco, director of the Cerro Tololo installation, said in an interview that "a new era has begun in the study of the southern skies." The fully operational instrument will allow astronomers to test and possibly confirm the validity of the methods used to measure distances in the universe.

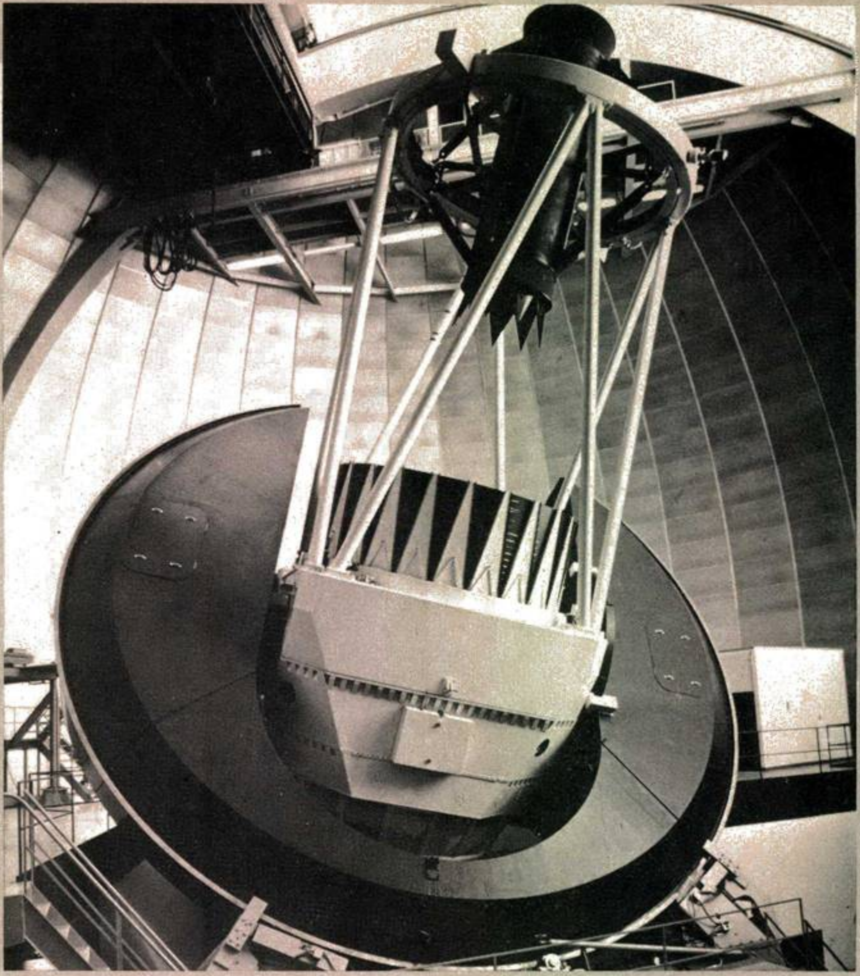
Blanco explained this " is fundamentally important to astronomy, if we are to better understand the nature of the universe as well as its components."

The 375 ton telescope, in part-time operation since last year, is the twin of the Kitt Peak National Observatory instrument near Tucson (Ariz.) — its sister institution in the northern hemisphere. Both are exceeded in mirror size only by the 200 inch telescope at Mt. Palomar. A 236 inch colossus at the Crimea Observatory in Russia will become the world's largest telescope when completed.

Cerro Tololo is located about 300 miles north of Santiago. Ideal climatic conditions create a viewing window that is rated excellent.

Both Cerro Tololo and Kitt Peak are operated as national research centers. Up to 60 percent of all telescope time is made available to visiting qualified astronomers who otherwise have no access to instrumentation capable of conducting frontier astronomical research.

Seven other telescopes share the mountaintop facilities of Cerro Tololo. They include a 24 inch Schmidt on loan from the University of Michigan and a 59 inch reflector.



The 158 inch Cerro Tololo telescope, 300 miles north of Santiago, Chile, is the southern hemisphere's largest eye on the universe. The movable portion of the 45 foot long, $10 million telescope weighs 300 tons, yet it is so well-balanced that it can be moved by one hand. Kitt Peak Observatory photograph.

Helios 2 to Study Sun During Record Fly-By

The second Helios space probe to study the sun's characteristics and effects on Earth was launched in mid-January from Cape Canaveral.

Designed to fly closer to the sun than any previous artificial satellite, Helios 2 will follow a highly elliptical orbit around the sun ranging from 90 million to 27 million miles. It will fly nearly two million miles closer to the sun than its predecessor which was launched a year ago.

A joint United States-West German project, the satellite will measure solar wind, galactic and solar cosmic radiation, magnetic fields and the diffuse glow seen on Earth in the east and west before sunrise and after sunset known as zodiacal light.

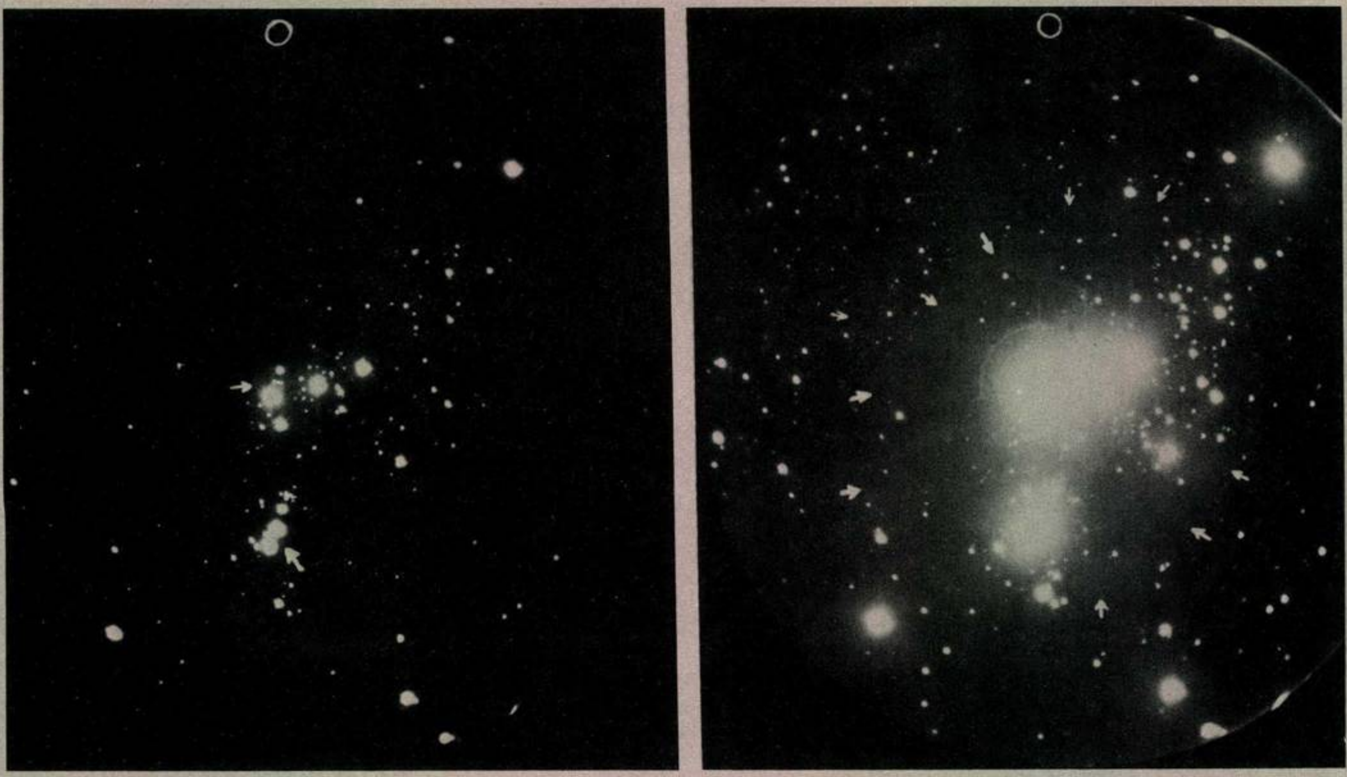
Surveys of the number of micrometeorites will be conducted to check the unexpected results observed by Helios 1. That probe detected about 15 times more micrometeorites close to the sun than measured near Earth. They were observed to originate from sharply defined but different directions at different times.

"We don't know whether they are transported by the sun's corona after being pulled into the sun from elsewhere in space," Dr. James Trainor, the U.S. project scientist explained, "or whether they may be following the path of starlight directly in toward the sun."

The West German-built craft will also conduct experiments in celestial mechanics to test Einstein's general theory of relativity by measuring the actual orbit of the satellite and comparing it with the plotted orbit.

Einstein's theory predicts that strong gravitational fields bend light in toward the source of the field as the light passes by.

Orion in Far-Ultraviolet Light



This photograph of Orion in far ultraviolet light was obtained by an electronic camera mounted on an Aerobee rocket. Young, hot, massive blue stars like these do not show up prominently in visible light because early in life they radiate most intensely in the ultraviolet. On the other hand, red Betelgeuse (circled in the upper portion of both photos), is the 2nd brightest star in the constellation to naked eye observers, but does not appear in the ultraviolet. The 30 second exposure (left) shows the Orion nebula and a nebula near Zeta Orionis, indicated by arrows. The 100 second exposure (right) details an extended nebulosity known as Barnard's loop, the result of reflection of ultraviolet light of the newborn stars by interstellar dust. The photographs should help astronomers identify the nature and composition of interstellar dust — the building block of star formation. Naval Research Laboratory photograph.

Two New Apollo Asteroids Detected

Two new Apollo asteroids — one whose orbit is closer to Earth's than any other body except the moon — have been discovered.

The second asteroid discovered, 1976AA, orbits between 73 million and 106 million miles from the sun — a mere 10 million miles from Earth's orbit on its closest approach. Discovered on Jan. 7 by California Institute of Technology scientist Eleanor Helin, 1976AA has a 19 degree inclination to the ecliptic, making a collision with Earth highly unlikely. (Dr. Eugene Shoemaker of Caltech computed the collision probability to be 1 in 24 million.)

Shoemaker believes the asteroid "probably is a specimen of what (is considered) to be a planetesimal — a building block of planets."

Because 1976AA is so close, Shoemaker suggested that it "provides a very attractive target for man's first venture into deep space." The asteroid's gravitational field is so small that landing on it "would be like docking with another spacecraft," Shoemaker said.

Charles Kowal, the astronomer who recently discovered Jupiter's 13th and 14th moons, detected 1975YA two weeks before 1976AA's discovery. At first believed to orbit between Venus and Earth, subsequent calculations showed it orbiting between Earth and Mars, making it the 19th Apollo asteroid to be discovered.

Apollo asteroids are a family group of minor "planets" whose orbits cross Earth's path around the sun. They are believed to be defunct comets who will end their days by colliding with our planet.

Both asteroids were discovered with the 18 inch Schmidt telescope at Palomar Observatory.

Radio Waves Find Carbon Monoxide On Venus, Mars

Though the presence of carbon monoxide in Venus' atmosphere was established in the early 1960s by infrared spectra, the molecule is the first to be detected by microwave radio spectra in a planetary atmosphere other than Earth's.

Two researchers from the Jet Propulsion Laboratory and one at the Electronics Research Laboratory (of the Aerospace Corporation) reported the discovery in the Jan. 30 issue of **Science**. They postscripted their report with the announcement of microwave detection of carbon monoxide in the Martian atmosphere as well.

Carbon dioxide, oxygen, sulfuric acid and hydrochloric and hydrofluoric acid are established components of Venus' cloud cover.

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Central Radio Source Located In Milky Way

Four astronomers at the Owens Valley Observatory of the California Institute of Technology have reported the discovery of a central radio source in the Milky Way.

Using a long baseline interferometer consisting of telescopes at Goldstone, Calif. and near Bishop, Calif., the group resolved the direction of the source and assigned it an upper size limit of less than 20 billion miles.

The astronomers believe their discovery is a redetection of a source found but not resolved by two astronomers in 1974.

The source's temperature, based on the observed variable brightness, is believed to be about 50 million degrees Fahrenheit and is expending energy at a rate equal to 100 million 100-megaton hydrogen bombs exploding each second.

The group suggested that because the observed brightness temperature is so high, radio waves are not generated thermally. Dr. Marshall Cohen, one of the four scientists, suggested the signals may be generated by "high energy electrons spiraling in a magnetic field" (synchrotroning) — a common process of radio wave production. The Crab nebula, a particularly powerful radio source, produces radio waves by this method, leading the scientists to speculate that a pulsar is the source of the energy output.

Compared to other discovered galactic center radio sources, this one is somewhat puny. Because it is so weak, it is doubtful whether it could be detected by an observer in another galaxy.

Potassium Found In Io's Clouds

A third element, potassium, has been found in the doughnut shaped sodium and hydrogen clouds of Io, Jupiter's third largest satellite. Lawrence Trafton of the University of Texas recently reported potassium spectra from Io's clouds in **Nature**. The information was detected by the 107 inch telescope at the university's McDonald Observatory.

Trafton suggested potassium is present because the innermost moon's surface microstructure is rough enough for multiple scattering of "sputtered" (atoms chipped off a solid surface by high energy protons or electrons) products to occur. (See "Io", February 1976.)

Soviets Announce Optics Discovery

Eight Soviet scientists have announced the discovery of a new light scattering phenomenon they claim will revolutionize optics and physics.

In an article recently published in **Sovietskaya Litva**, the scientists claim their discovery reduces many present laws of optics to approximations, valid only for low intensity light levels.

The scientists reportedly sent a powerful laser beam into a transparent crystal, and certain discrete frequencies of the electromagnetic spectrum appeared. They said that frequency distribution can be altered by changing the orientation of the crystal, placing it in a magnetic field or varying its temperature.

Some of the observed effects are predicted by quantum mechanics.

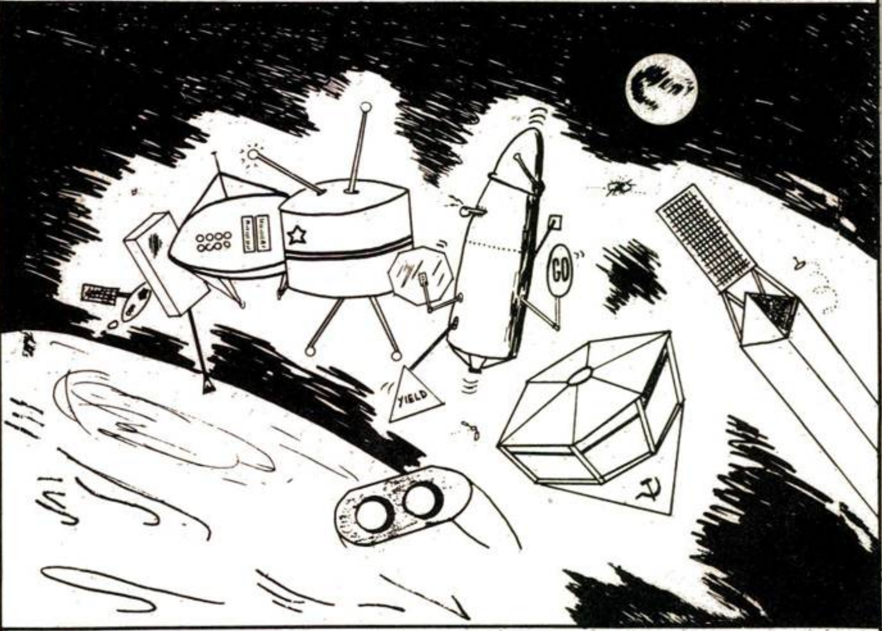
It has been believed that monochromatic light (light of a single color such as produced by lasers) cannot be broken down further.

The discovery has been certified by the Soviet State Committee of Inventions and Discoveries.

Initial reaction of Western observers has been skeptical. One expert, who asked not to be identified, said the discovery reminded him of the "Polywater affair" of several years ago — a reference to a Soviet scientist's "discovery" of a new water polymer. It was eventually determined that his findings were based on impure water samples.

Soviet scientists and laboratories are known to operate under a quota system. Scientists must earn a certain number of Certificates of Discovery, while labs are assigned discovery quotas under the present Soviet Five-Year Plan. Scientists, one source observed, "sometimes go to great lengths to convince the Committee (of Inventions and Discoveries) of their sincerity" when they know their discoveries are not factually based.

"I Said We Should Have Avoided the Rush Hour!"



With the recent Soviet announcement of plans to orbit seven more communication satellites by 1980, together with an American satellite builder's prediction of over 40 international and domestic satellites competing for desirable stations above the equator by 1985, fears of orbital crowding are intensifying. Adding to the probability of a satellite crunch in space are plans by Indonesia, Japan, Brazil, Iran, Australia and the Arab League to launch relay satellites for domestic systems. Possibilities of radio interference between swarms of satellites will be discussed at the upcoming International Telecommunications Satellite Consortium (Intelsat) conference in Geneva. Intelsat, with 91 member nations, has already placed five generations of satellites in Earth orbit, and plans to launch a sixth by 1979.

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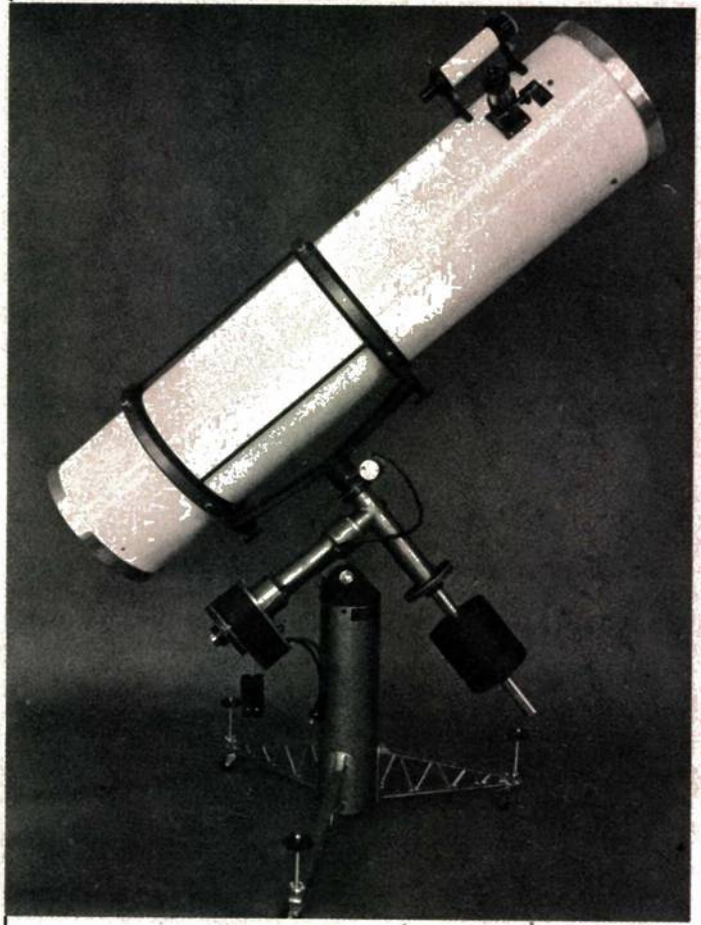

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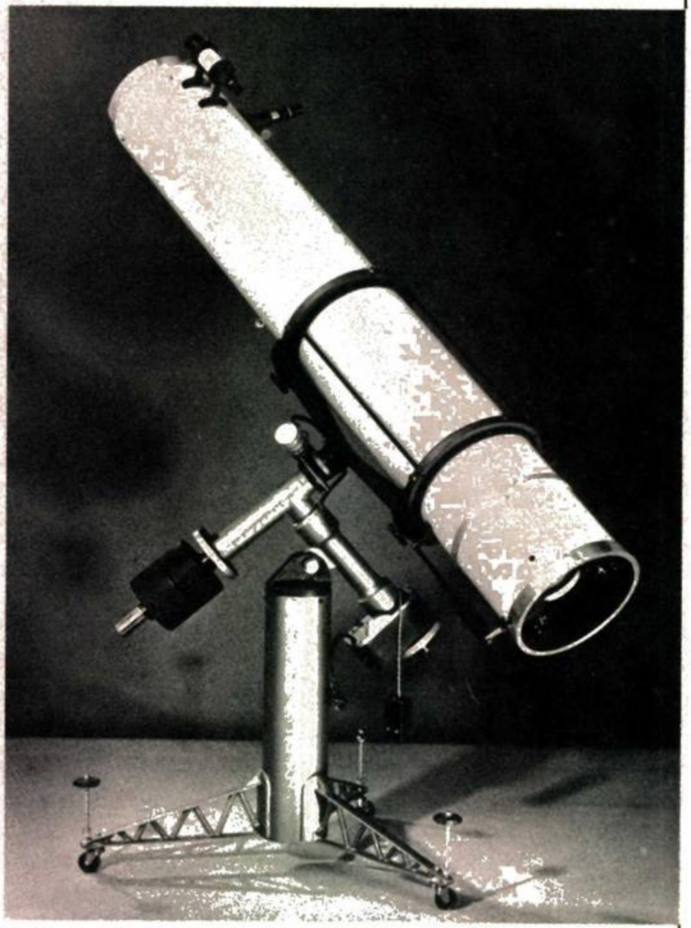

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STELLAR FRONTIERS

Life's Protective Shield

by

Gerrit L. Verschuur

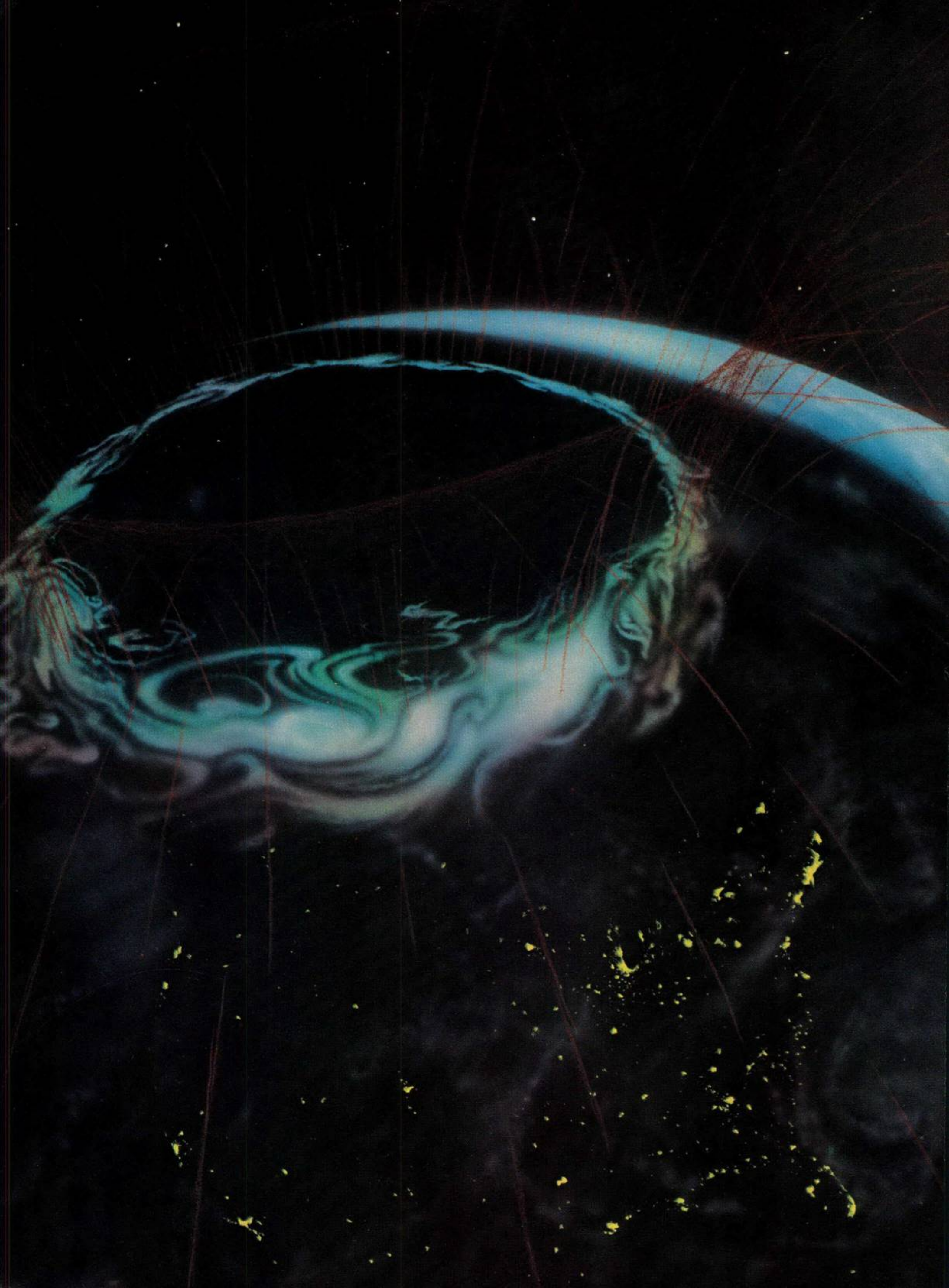
Humans tend to believe that life on Earth exists in a sort of grand isolation from the rest of the universe; that evolution is determined exclusively by changes on the planet's surface or in its atmosphere. We know that various species of animal and plant life evolve, survive or die, depending on how capably they adapt to environmental changes. But we usually don't realize that such changes can be brought about by events that have occurred even in other galaxies.

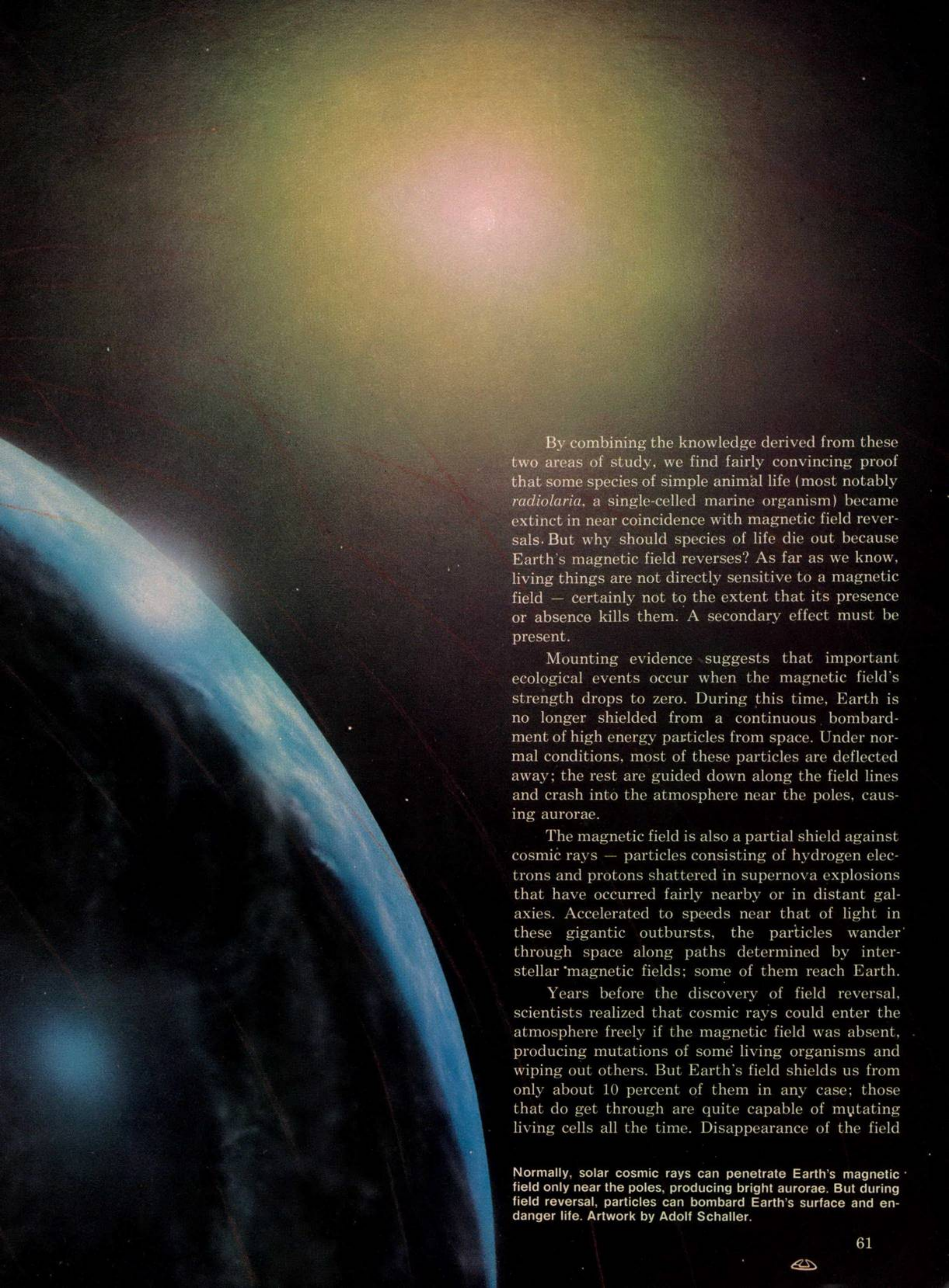
One of the mysteries unveiled through study of Earth's fossil history is that at various times, and for no apparent reasons, whole families of living things have vanished within a relatively short time. The extinction of the dinosaurs some 70 million years ago is the best known example of just such a disappearance. Over the last few decades, scientists have advanced several theories to explain these mysterious extinctions, but none have been to everyone's satisfaction. Now another theory has been proposed, linking the reversals of Earth's magnetic field to the disappearance of several species of simple life forms.

Scientists know that in the past, Earth's magnetic field has shown several reversals in direction. At present the north magnetic pole is defined as the region to which the north poles of magnets are attracted. When Earth's field reverses, this region assumes the opposite, or south, polarity; it might also have a slightly different geographical location. Theories as to why Earth has a magnetic field at all are not well enough developed to explain why polarity should reverse, but we know that in the last 4-1/2 million years, it has done so about 20 times.

These field reversals have been revealed by measurement of the direction of magnetization in sedimentary rock layers and in the remains of lava flows. Magnetism can be "remembered" by rocks formed under certain conditions. For example, when molten lava flows in the presence of a magnetic field, its particles of matter are aligned by the field and frozen into that particular orientation when the lava solidifies. From then on, the rocks preserve a record of the field under which they formed. Lava flows from various past ages show that Earth's field was not always polarized in the same direction as it is now. Sedimentary rocks also "remember" the direction of the ambient magnetic field at the time of their deposit, but here the mechanism is not yet known.

Disappearance of animal species has been discovered from study of their fossils. Remains of certain animals may be present in one rock layer and vanish from rocks several thousand years younger. The ages of rock layers can be determined from the extent of decay of the radioactive elements bound within the layers.





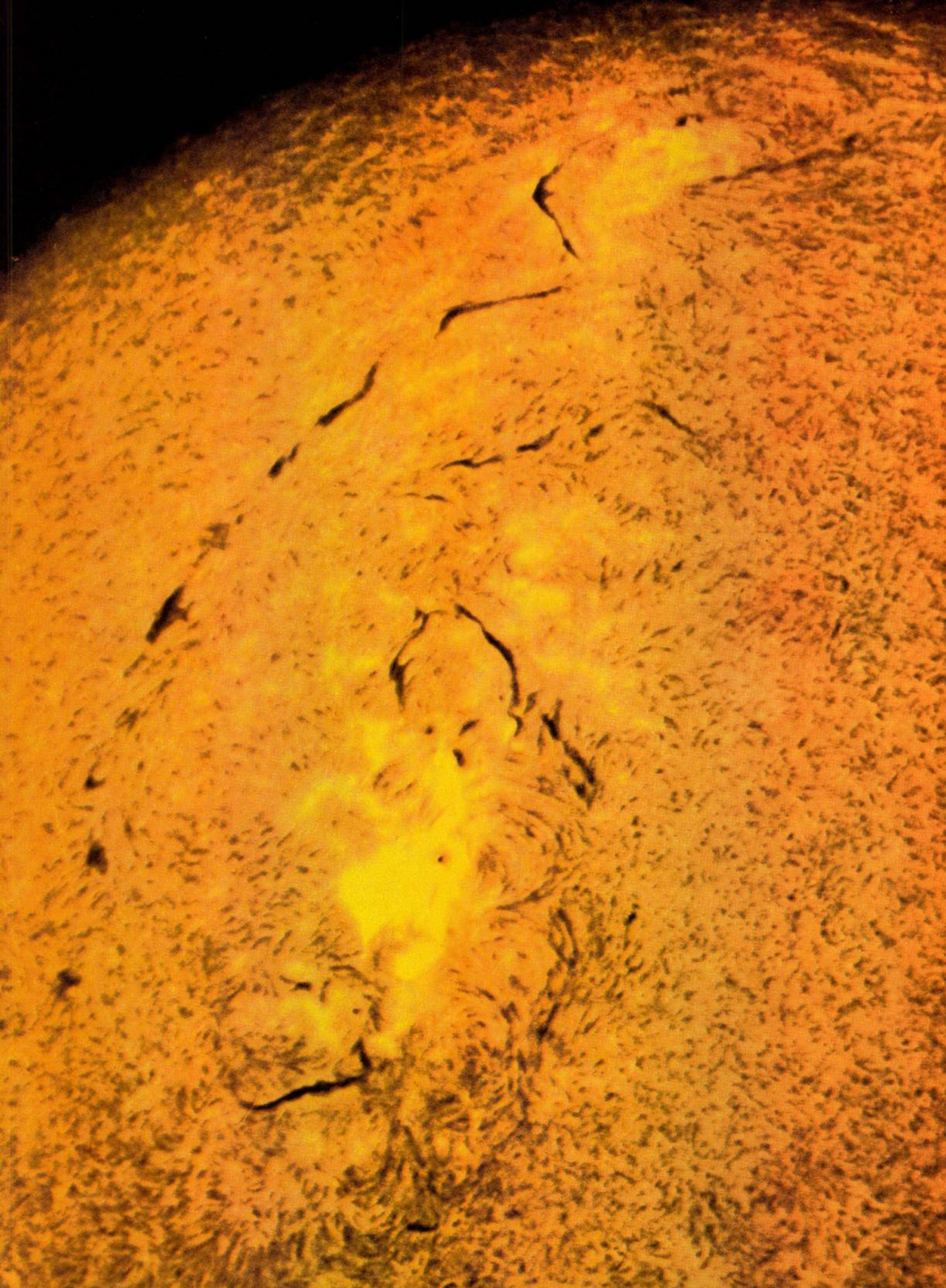
By combining the knowledge derived from these two areas of study, we find fairly convincing proof that some species of simple animal life (most notably *radiolaria*, a single-celled marine organism) became extinct in near coincidence with magnetic field reversals. But why should species of life die out because Earth's magnetic field reverses? As far as we know, living things are not directly sensitive to a magnetic field — certainly not to the extent that its presence or absence kills them. A secondary effect must be present.

Mounting evidence suggests that important ecological events occur when the magnetic field's strength drops to zero. During this time, Earth is no longer shielded from a continuous bombardment of high energy particles from space. Under normal conditions, most of these particles are deflected away; the rest are guided down along the field lines and crash into the atmosphere near the poles, causing aurorae.

The magnetic field is also a partial shield against cosmic rays — particles consisting of hydrogen electrons and protons shattered in supernova explosions that have occurred fairly nearby or in distant galaxies. Accelerated to speeds near that of light in these gigantic outbursts, the particles wander through space along paths determined by interstellar magnetic fields; some of them reach Earth.

Years before the discovery of field reversal, scientists realized that cosmic rays could enter the atmosphere freely if the magnetic field was absent, producing mutations of some living organisms and wiping out others. But Earth's field shields us from only about 10 percent of them in any case; those that do get through are quite capable of mutating living cells all the time. Disappearance of the field

Normally, solar cosmic rays can penetrate Earth's magnetic field only near the poles, producing bright aurorae. But during field reversal, particles can bombard Earth's surface and endanger life. Artwork by Adolf Schaller.



would therefore produce a negligible increase of cosmic rays from distant space.

However, smaller explosions called flares take place on the sun; they emit large amounts of less energetic cosmic rays — particularly protons. The number is overwhelming compared to the amounts that reach us during quiet solar conditions. Earth's magnetic field can usually deflect these less energetic particles; some of them are trapped in the Van Allen belts; only a few can reach the atmosphere, and then only near the poles, where they pose less of a threat to life.

But if the magnetic field were removed for a few thousand years, a solar flare would send protons crashing down over the entire planet — not just near the poles. The increased proton dose may very well be the crucial factor influencing life on Earth, by originating the following chain of events.

When protons collide with molecules in Earth's atmosphere, the molecules are shattered — resulting in an enormous number of particles called *secondary electrons*. These are electrons stripped from their molecular orbits by the collision. The secondary electrons strike nitrogen molecules, reducing each to its two constituent nitrogen atoms. In many cases, one of the atoms so formed may also lose an electron — that is, it may become *ionized*. Next, these ionized nitrogen atoms combine with oxygen molecules, forming oxygen atoms and nitric oxide (NO).

This is where the trouble starts, for NO proceeds to combine with the atmosphere's ozone to form nitrous oxide (NO_2) and oxygen. The ozone is removed and nitrous oxide, in turn, combines with more oxygen atoms to form nitric oxide again — thus leaving the original amount of NO available to destroy more ozone.

Ozone is essential for survival of life on Earth because it absorbs the ultraviolet radiation that reaches us from the sun. This ultraviolet can destroy living tissue, increase incidence of skin cancer or radiation burns, and directly influence mutation of organisms. The ozone layer high in the atmosphere shields us from these harmful effects — but it cannot if it is removed.

This process, incidentally, could result if large numbers of supersonic transport planes were to fly in the high atmosphere, since these planes spew out the identical nitrogen oxides that can reduce the ozone layer.

We can now see that Earth becomes very vulnerable to proton storms when its usual magnetic defenses are down; entire species of primitive organisms appear to have been wiped out during such times in the past. Calculations and computer simulations show that the mechanism just described could work.

The susceptibility of simple organisms to destruction by ultraviolet radiation has been measured in the laboratory, proving that many such organisms can tolerate only a small increase of ultraviolet before they die. If these organisms were killed off, the consequences to our ecological system — in which one organism depends on many others for survival — could be extensive.

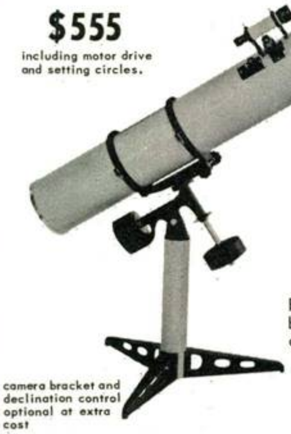
We can now consider the disappearance of the dinosaurs: Did it occur as a result of a field reversal on Earth occurring simultaneously with severe solar flares? There is, unfortunately, no way of telling, because measurements of Earth's magnetic field do not extend far enough into the past. However, the dinosaurs were active and successful for nearly 200 million years, and they must have survived many field reversals without incident during that long time. It is difficult to explain why one more reversal should have caused their extinction.

If all the data on field reversal is taken at face value, there have been long periods of about a million years during which no reversals occurred, and it stayed substantially the same — only flipping back and forth occasionally. However, over the last 600,000 years there have been no well-established reversals. We might speculate that regular field reversals would force the survival of the most adaptable species, while larger changes would occur if a reversal takes place after a long quiescent period — of, for example, 600,000 years. Many life forms might be incapable of dealing with increased proton dosage or the associated ultraviolet increase.

We don't know when the next field reversal may start. Currently, Earth's magnetic field is decreasing very slowly; if it continues at its present rate, the field's strength would reach zero in 1,000 or 1,500 years — once again making life vulnerable to the sun's proton storms. Whether or not *homo sapiens* would suffer is uncertain, but we may be able to take solace from the fact that man has shown himself to be a very adaptable species thus far.

Such discoveries as these help us place ourselves, and our position in the universe, in greater perspective. The heavy elements in our bodies and in our planet all originated in exploding stars; cosmic rays from dying stars can help produce mutations in life on Earth, and if a supernova explodes near the sun, the subsequent cosmic ray dose could prove fatal to many life forms. Cosmic rays might even be the cause of the electricity in the atmosphere that generates lightning during thunderstorms. Our existence, and the course of our evolution, are quite clearly related not only to events in our little corner of the universe, but also to other events occurring on a cosmic scale.

A flare such as the one pictured here is an explosion on the sun that spews out great numbers of cosmic ray particles. Earth's magnetic field can protect us from these floods of protons. But if large flares occur simultaneously with field reversal — when Earth's magnetic field is at its weakest — the increased cosmic ray dose can remove the ozone in the atmosphere, leaving Earth life at the mercy of dangerous ultraviolet radiation. NASA/N.O.A.A. photograph.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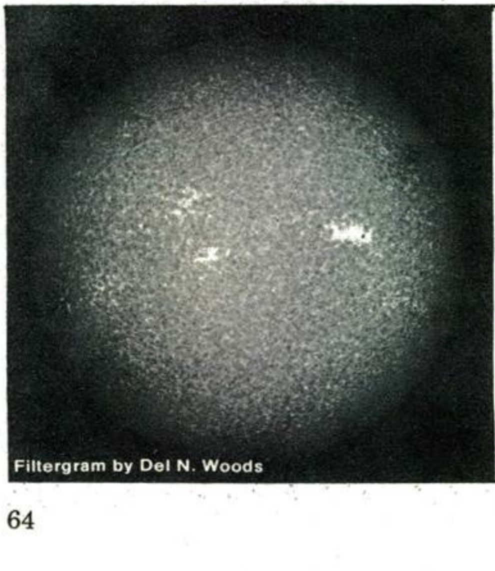
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continued from page 49

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ASTRONOMY

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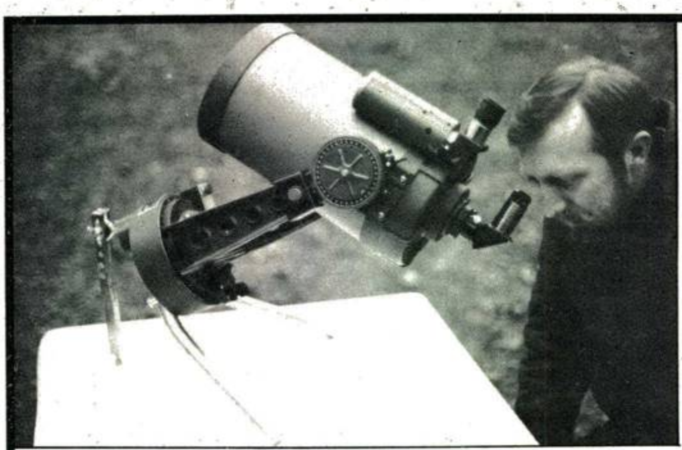

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MARCH

by

James Mullaney and Henry J. Phillips

Spring has a way of sneaking up on us. We look forward to its arrival every year, of course, and everyone knows the date of its beginning — March 21 (although this year it happens to start a day earlier). Nevertheless, winter always seems to drag on forever, and the arrival of warmer weather usually takes us by surprise.

So it is with the spring constellations. The winter groups are so bright, prominent and full of interesting objects that they invite our undivided observation even after they have passed their zenith and are beginning to sink in the west. This month, if we manage to pull our attention away from these constellations, it is almost with a sense of shock that we realize many of the spring patterns are already halfway up the sky.

The reason we haven't noticed the spring stars earlier is their lesser brilliance. Already the contrast is marked: while we find a great many bright stars, not to mention the Milky Way, in the western half of the sky, the east seems nearly empty by comparison. The temptation to take one last look at the winter constellations is probably an irresistible one for many successive nights during March.

When investigating the myths connected with our constellation figures, we tend to concentrate on the Greek and Roman legends to the exclusion of all others. The constellation names are, of course, the Greek or Latin titles, and the stories we know are those of the Greeks — being the most famous, the best preserved historically, and the most easily accessible. Yet these factors may leave the impression that the constellations were invented all at once during a time only a few centuries B.C.

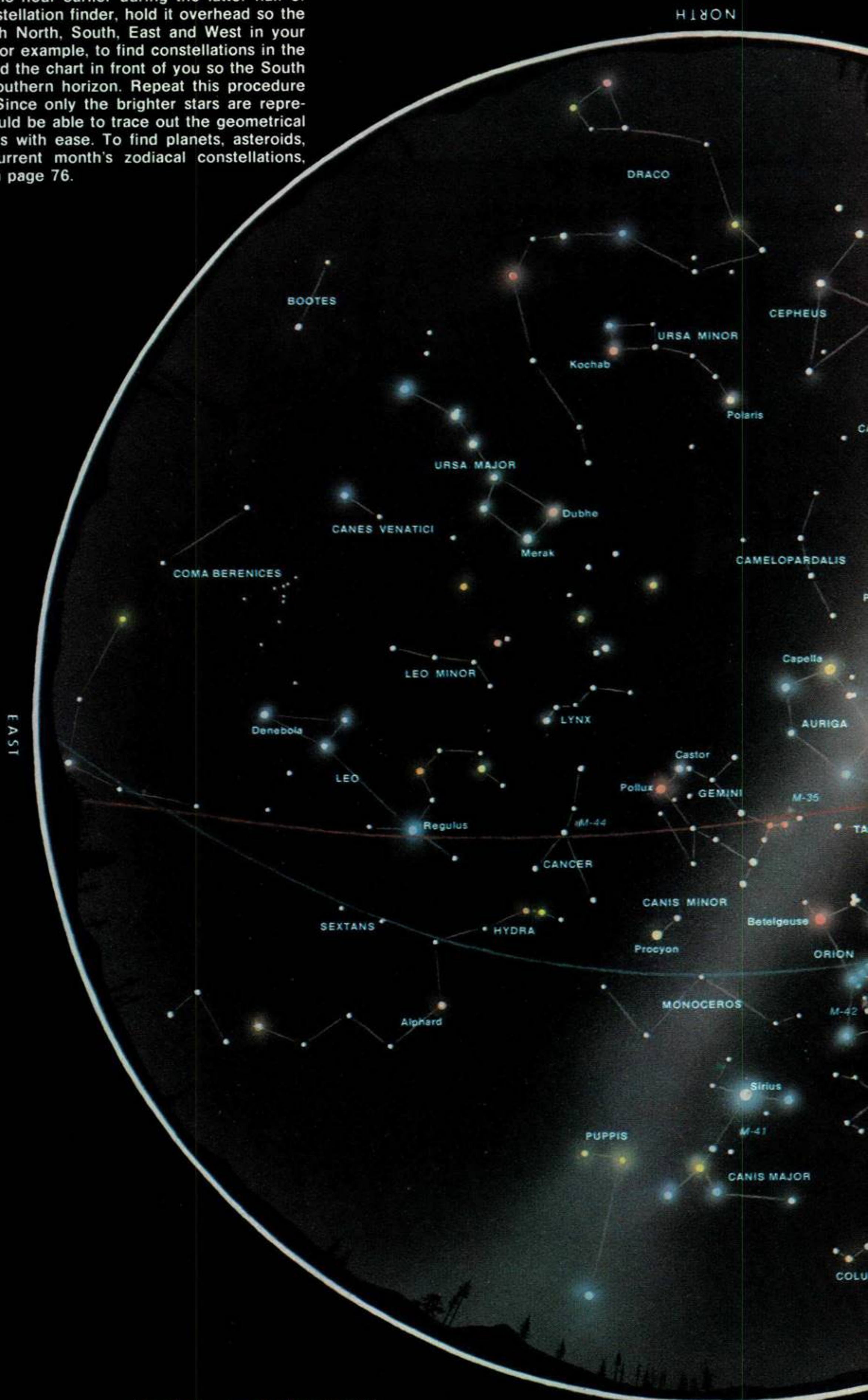
This is not so. Strictly speaking, we cannot say that anyone "invented" the constellations. They were self-evident from prehistoric times, and only needed identification. If this statement needs proof, consider that anyone with a complete lack of knowledge of the constellations can instantly pick out the stars of Orion, or the Big Dipper, as a distinct and recognizable group — hardly a case of inventing a constellation.

In fact, most of the current figures had been identified by the time of the Chaldeans (about 2000 B.C.), and the Greeks took over these groups, in many cases merely translating the names into their own language. The stories were grafted on later, and the Greeks sometimes had to dig pretty deep to find an adequate tale. Other stories had the effect of changing a constellation's entire character. A case in point is provided by Perseus, whom we know today as one of the players in the well-known Andromeda myth — the hero, in fact. But before the Greek era, Perseus had nothing to do with Andromeda. It was an unlucky group containing the most ominous star in the sky: Algol, the demon — the only star that visibly changed its brightness. We can see that the Greek story gives us today an entirely different conception of Perseus.

We sometimes assign a constellation to a certain season and remain somewhat oblivious to its prominence during other parts of the year. Perseus, now going down in the northwest, is known as a fall group, yet it is high in the sky throughout winter and early spring — higher than many of the "winter" figures nearby.

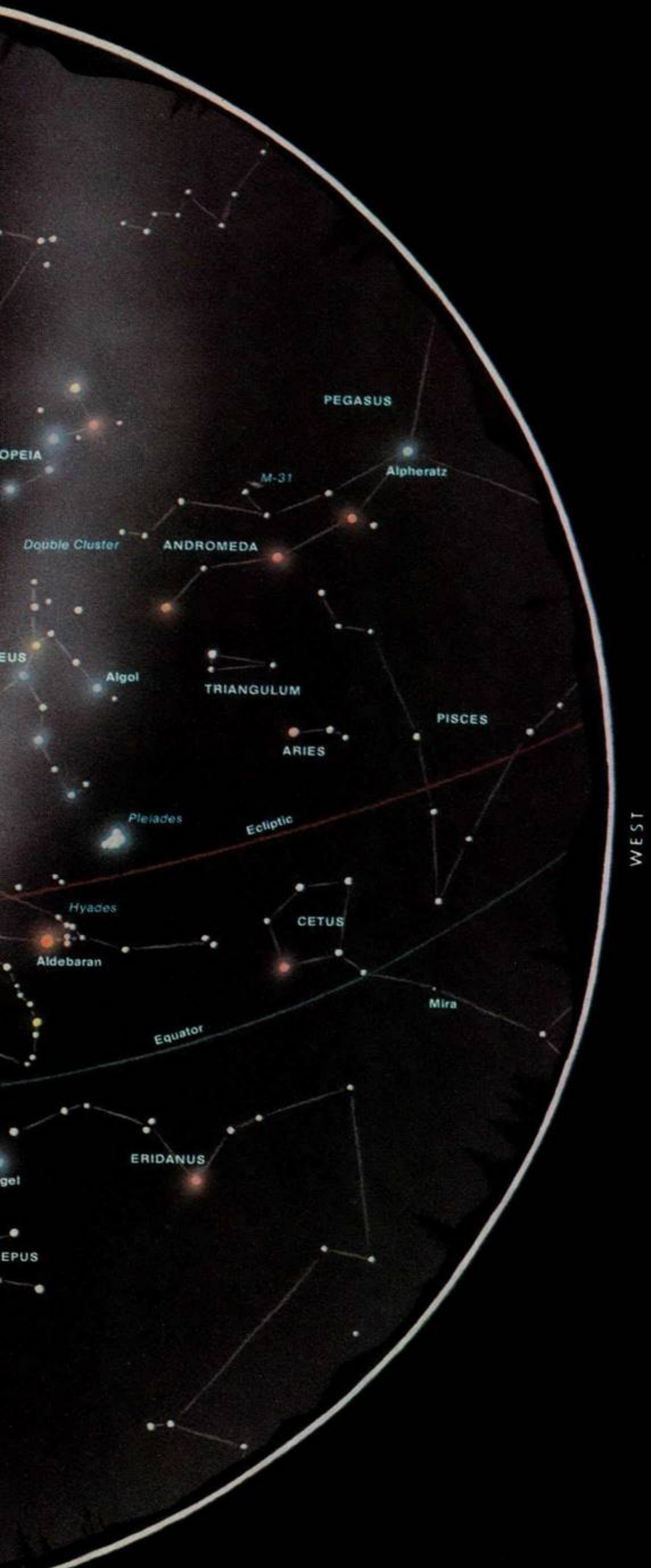
Auriga is the farthest north of the winter groups and will therefore be the last one to set. The glit-

This Star Dome rendering approximates the sky as it appears at about 8 p.m. Local Standard Time early in the month. The same constellations are visible one hour earlier during the latter half of the month. To use this constellation finder, hold it overhead so the compass points line up with North, South, East and West in your backyard or viewing area. For example, to find constellations in the southern part of the sky hold the chart in front of you so the South compass point faces the southern horizon. Repeat this procedure for East, West and North. Since only the brighter stars are represented in this map, you should be able to trace out the geometrical shapes of the constellations with ease. To find planets, asteroids, etc., visible among the current month's zodiacal constellations, refer to the planet finder on page 76.


NORTH
DRACO
BOOTES
CEPHEUS
URSA MINOR
Kochab
Polaris
URSA MAJOR
Dubhe
CANES VENATICI
Merak
COMA BERENICES
CAMELOPARDALIS
LEO MINOR
Capella
EAST
Denebola
LYNX
AURIGA
LEO
Castor
Pollux
GEMINI
M-35
Regulus
M-44
CANCER
CANIS MINOR
SEXTANS
HYDRA
Betelgeuse
Procyon
ORION
MONOCEROS
M-42
Alphard
Sirius
PUPPIS
M-41
CANIS MAJOR
COLU

Map Centered on 40 North Latitude

SOUTH



Map by Adolf Schaller

tering first magnitude star Capella marks the upper right corner of its unmistakable pentagon shape as well as the top of winter's "great circle" of first magnitude stars. Of all the stars in this circle, only Sirius is brighter.

The stars of Auriga have represented a charioteer since the time of ancient Babylon. Storytellers have been hard put to find a more exact identification; the one usually given is Erichthonius, a son of the lame god Vulcan and inventor of the chariot. But no important mythical figure was ever pictured in Auriga, and he may seem a little out of place among all those gods and heroes.

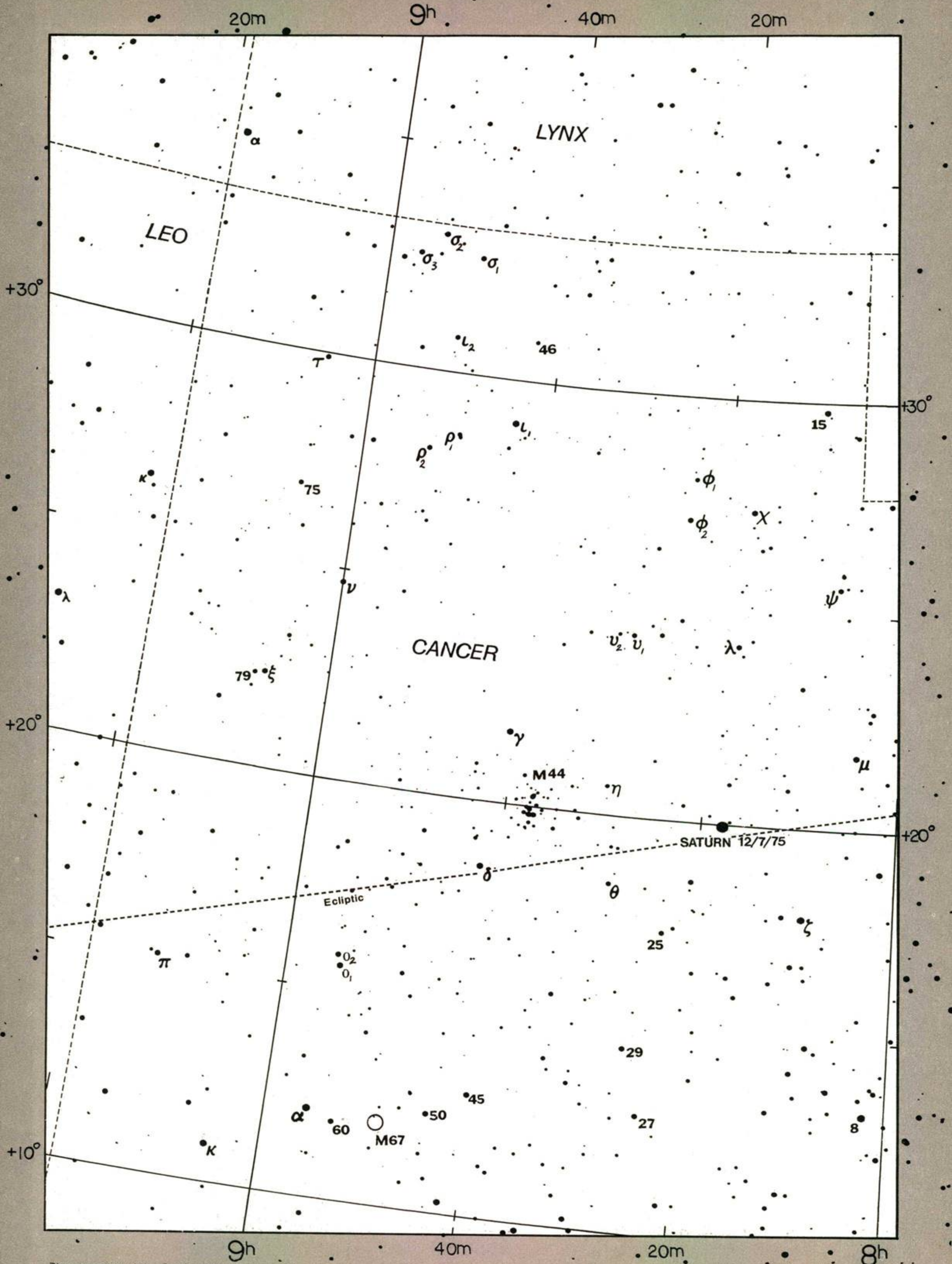
The southernmost star in the pentagon technically belongs to Taurus. It forms both the charioteer's foot and one of the bull's horns, thus presenting us with the comical picture of Auriga standing placidly on Taurus' horn as that animal angrily rushes Orion.

The name Capella means "little she-goat," and a goat is usually shown perched on the charioteer's shoulder. The star is the fourth brightest in our latitudes, and the spectroscope reveals that Capella is a close binary — so close that our largest telescopes cannot separate the two components. This is also the case with Auriga's second brightest star, located at the northern tip of the pentagon. This star's mellifluous name is Menkalinan — from the Arabic and meaning nothing more than "right shoulder of the charioteer." It is one of the 30 brightest stars in the sky.

Just north of Auriga is the constellation Camelopardalis. This is another of the modern constellations we discussed here last month. There appears to have been some confusion in the past about its name: It has been called Camelus, Camelopardus, and Camelopardalis. The latter name, which means giraffe, is the title accepted today. Just why anyone found the group important enough to argue about its name is unclear, for this is one of the true wastelands of the sky. It contains only a few naked eye stars (none brighter than fourth magnitude), and the casual observer usually does not waste his time in this dull area.

But Camelopardalis does have one distinction. There are six circumpolar constellations in our northern sky. We all know five of them: Ursa Major, Ursa Minor, Draco, Cassiopeia and Cepheus. The sixth is generally forgotten — and it is Camelopardalis. The dim, neglected giraffe thus finds itself in very select company indeed.

March is a month in which many faint stars are at their highest. Not only Camelopardalis, but also Lynx and the western part of Ursa Major are in good positions for observing, as well as the most inconspicuous of the 12 zodiacal constellations — Cancer the crab. Flanked by Regulus in Leo to the east and Castor and Pollux in Gemini to the west, this misty configuration of stars contains no object brighter than fourth magnitude. Yet Cancer is an important


20m
9h
40m
20m
LYNX
α
LEO
σ2
σ3
σ1
+30°
ι2
46
τ
+30°
15
ι1
ρ1
ρ2
κ
75
φ1
φ2
χ
ν
λ
ψ
υ2
υ1
λ
CANCER
79
ξ
+20°
γ
μ
M44
η
SATURN 12/7/75
+20°
δ
θ
Ecliptic
ζ
25
π
o2
o1
29
45
α
50
60
M67
27
8
κ
+10°
9h
40m
20m
8h

Photograph by John Sanford/Map by Victor Costanzo celestial landmark and holds much of interest to the visual observer.

The Chaldeans gave this constellation its name because the crab's backward or oblique walk typified the sun's apparent retrograde movement in this part of the sky centuries ago. Cancer at that time contained the summer solstice, which has since shifted to neighboring Gemini due to precession. The solstice is the point on the ecliptic occupied by the sun on the first day of summer (its highest point in the sky for northern hemisphere observers).

This important status is still remembered here on Earth in the Tropic of Cancer, the circle of latitude at 23 degrees north. This is the latitude at which the sun appears directly overhead at noon on the first day of summer.

Within Cancer is a hazy patch of light called, by the ancient Greeks, the Little Cloud, Cloudy One or Whirling Cloud. It was also called, and is still known as, Praesepe (the manger). This open cluster of stars — popularly titled the Beehive — is discussed in Close-Up and Eyepiece Impressions below.

The stars Gamma and Delta on either side of the cluster bear the Greek names Asellus Borealis and Asellus Australis. These titles mean the northern and southern ass, which both the Greeks and Arabs imagined to be feeding at the manger.

At least one ancient legend concerning Cancer involves these two animals. The god Bacchus, on his way to the temple of Jupiter, came to a swamp that blocked his way. Noticing two wild asses grazing in a nearby field, he mounted one of them and crossed the marsh without incident. In gratitude for this service, he transported both creatures to the heavens for eternity.

Greek legend involves Cancer with Hercules during his famed contest with the dreadful Lernean hydra. The goddess Hera, who hated the mighty hero, sent a crab to attack him, hoping to distract Hercules' attention long enough for the hydra to destroy him. But Hercules merely crushed the crab and went on with his battle. To reward the poor crab for its futile sacrifice, Hera persuaded Zeus to immortalize the creature by placing it in the sky.

The fourth magnitude star Alpha Cancri is known as Acubens, meaning the claws. As with other constellations we have discussed, Alpha should be the brightest star in Cancer according to the Bayer Greek letter scheme; but it isn't. At visual magnitude 4.27, it is outshone by Beta at 3.76, Delta at 4.17 and Iota at 4.20. The half magnitude difference between Alpha and Beta is especially obvious, and perhaps one of the involved stars has changed in brightness since they were designated.

In June 1895, all the known planets except Neptune were gathered in Cancer. Halley's comet also appeared here in 1531, nearly two centuries before Halley discovered its periodic nature and predicted its return.

Tracing out Cancer requires moonless nights and dark adapted eyes for success. In this, the crab provides excellent practice for the other spring constellations, most of which contain indistinct patterns and dim — but interesting — stars.

Close-Up on the Cancer Region

The body of Cancer is dimly outlined by an irregular square formed by fourth and fifth magnitude stars Gamma, Delta, Eta and Theta, while the claws are marked by a number of surrounding stars such as Alpha, Beta, Iota, Zeta and Xi. On a dark clear night, little imagination is required to see a huge crab stalking its neighbors in the sky.

To the unaided eye, the most interesting visual feature of Cancer is the loose open cluster of stars, M-44. Situated within the square mentioned above, this object looks very much like a large nebula to most eyes and has even been mistaken for a comet on occasion.

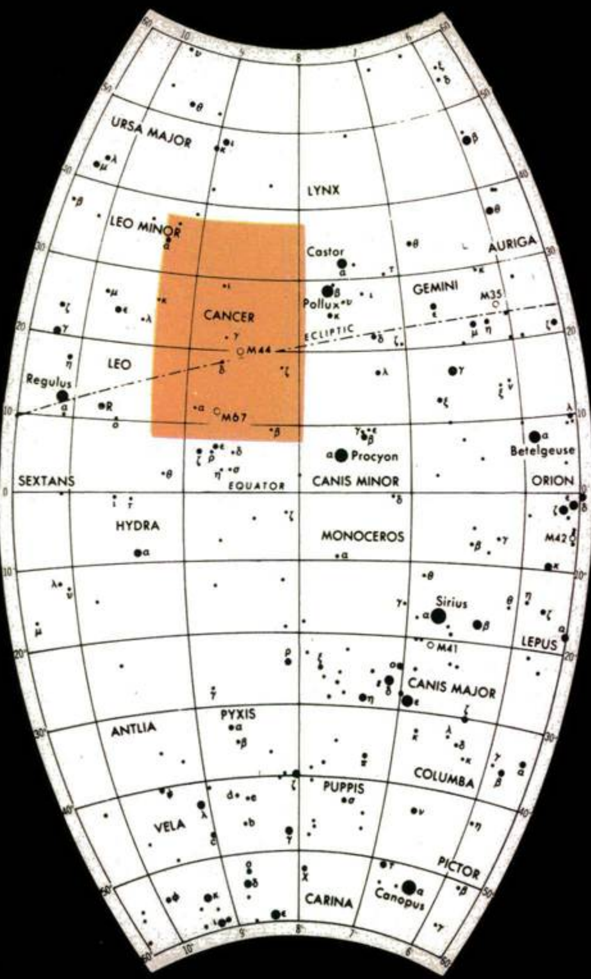
Known since Roman times as Praesepe, it is better known today as the Beehive. The origin of this name is unknown; it may refer to the cluster's roughly triangular, beehivelike shape, or perhaps an imagined resemblance to a cloud of cosmic bees swarming in the night.

Covering three full moon diameters of sky, this object is a fine sight in binoculars, finders and wide field instruments, but tends to be disappointing in most telescopes because of their inability to encompass the entire cluster at once.

In ancient times, visibility of the Beehive was regarded as a sort of visual barometer or weather forecaster. Aratus and Theophrastas, in 300 B.C., noted that the cluster's invisibility in an otherwise clear sky signaled the approach of a storm. Lying near the threshold of the eye, even the slightest obscuration by high altitude cirrus ice crystals is enough to render it invisible. These same crystals provide the halos seen around the sun and moon — also an omen of approaching weather fronts. M-44's use as a weather indicator is still effective today, so why not try it yourself on the fitful nights of early spring?

The brighter central portion of the Beehive is about 10 light-years across while the outer stragglers extend more than three times that figure in space. Its distance from us is about 500 light-years — relatively close as clusters go!

Binocular users will encounter a number of fine double and triple star combinations while sweeping in Cancer. Readers having 10 x 50 mm or larger instruments should try to split the beautiful double Iota 1 Cancri. These fourth and sixth magnitude suns are separated by a half minute of arc and present a stunning color contrast of orange and blue — much like famed Albireo in Cygnus. Mounting your



Map from **Guideposts to the Stars**; reprinted permission of MacMillan Publishing Co., ©1972 by Leslie C. Peltier

Stars in each constellation are indicated, in order of brightness, with the Greek Alphabet.

α	Alpha	η	Eta	ν	Nu	τ	Tau
β	Beta	θ	Theta	ξ	Xi	υ	Upsilon
γ	Gamma	ι	Iota	ο	Omicron	φ	Phi
δ	Delta	κ	Kappa	π	Pi	χ	Chi
ϵ	Epsilon	λ	Lambda	ρ	Rho	ψ	Psi
ζ	Zeta	μ	Mu	σ	Sigma	ω	Omega

Table of Selected Objects — Cancer Region

Object	Type	Mag.	Size/Sep.	R.A.(1950)	Dec.
CANCER					
•ζ(Zeta)	★3	5.7,6.0,6.0	1",6"	08^h09^m	+17°48'
φ2 (Phi)	★2	6.3,6.3	5"	08^h24^m	+27°06'
• M-44	OC	3.7	95'	08^h38^m	+19°52'
•ι1 (Iota)	★2	4.2,6.6	31'	08^h44^m	+28°57'
• M-67	OC	6.1	15'	08^h48^m	+12°00'
•ι2 (Iota)	★3	6.3,6.5,9.2	1.5",56"	08^h51^m	+30°46'
χ(Chi)	V:170^d	5.9-7.3	—	08^h53^m	+17°25'
RS	V:120^d	5.5-7.0	—	09^h08^m	+31°10'

• Detailed in Eyepiece Impressions

OC = Open Cluster
★ 2,3,4 = Double/ Multiple Star
V:# ^{dhms} = Variable Star, Period - days, hours, minutes
Mag. = Magnitude
Sep. = Separation

binoculars on a standard camera tripod with an adapter clamp (available from Edmund Scientific and other supply houses) can transform them into a very effective glass for deep sky observing. (See Equipment Atlas, January 1976.)

Because Cancer lies directly on the ecliptic (pathway of the sun, moon and planets), a number of its stars — particularly Delta and Gamma — are frequently occulted by the moon in its monthly passage through the constellation. The moon occasionally occults individual stars in the Beehive too, but due to their faintness, their blinkings in and out are much more difficult to observe than those of the Pleiades and Hyades.

Eyepiece Impressions

Zeta (ζ) Cancri

We begin our survey of Cancer's telescopic showpieces with an object that is a single, double, triple or quadruple star all in one — depending on just what size instrument is being used! This is fifth magnitude Zeta, to which a line from Castor through Pollux, extended southeast about twice their apparent separation, point directly.

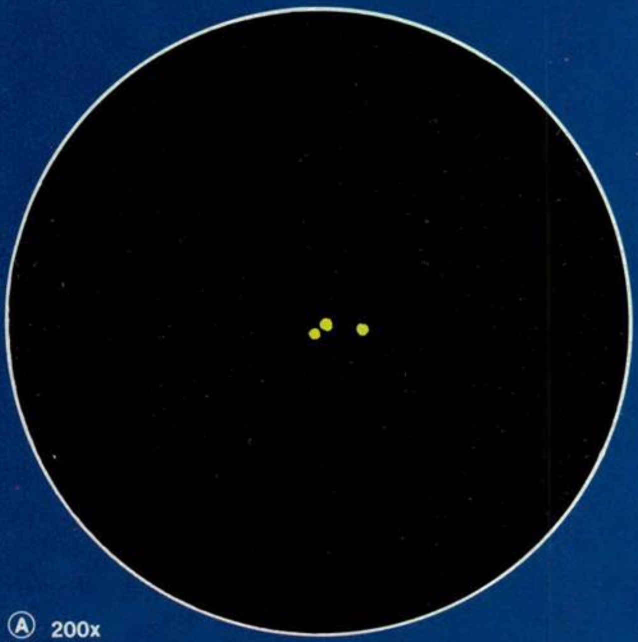
To the unaided eye Zeta appears single, but even a 2.4 inch (60mm) refractor at 70 power divides it into a pair of sixth magnitude stars six seconds apart. A four inch telescope near 200 power shows one of these stars to have its own sixth magnitude companion at just under one second's distance. This close pair is a binary having a period of 60 years. It was at its widest in 1960 — 1.2 seconds separation — and is now closing to a minimum near 0.5 seconds in 1990. A given telescope-eyepiece combination that just resolves this duo now should, over the next few years, show their images merging as the separation decreases — visual evidence of stellar motion!

In six inch and larger instruments, Zeta is an attractive but difficult triple; a 10 inch reflector at 320 power provides a thrilling view during good seeing conditions. All three stars appear yellow in hue, with some observers seeing a trace of orange.

Barns says that Cancer "offers many allurements" and lists Zeta as a test object, as does Webb in his description: "Excellent test, close pair well separated eight inch speculum... 300 (power) when 0.5 seconds; one disk apart 9.3 inch speculum... when 0.7 seconds, very easy at 1.0 seconds."

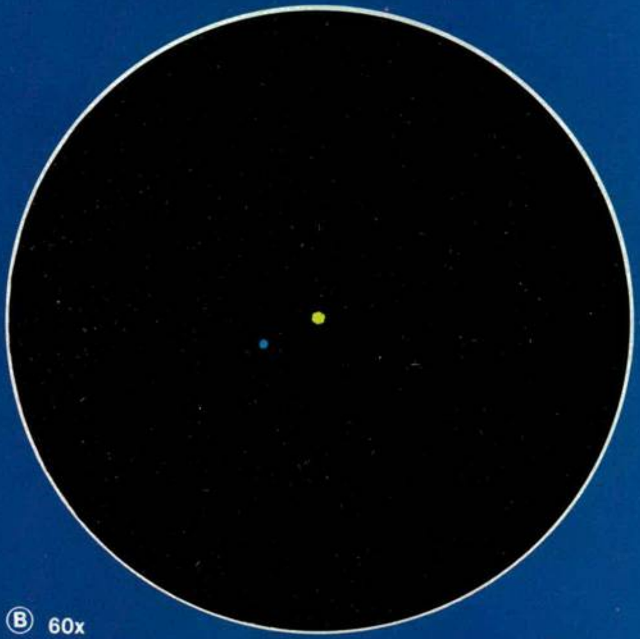
There is yet another almost visible astrometric member in this group — a 7.8 magnitude star only 0.2 seconds from one of the three sixth magnitude components. Deciding just which one is the double is for owners of large amateur instruments having first class optics. Such a telescope in good seeing may at times elongate the star that is the pair, which has an extremely short period (for a visual binary) of only 18 years.

Zeta Cancri



Ⓐ 200x

Iota-1 Cancri



Ⓑ 60x

Were we to extend our survey into the spectroscopic realm, we would find that there is still another member of this remarkable system. So if we were living on a planet orbiting Zeta Cancri, we would find at least five suns shining in our sky!

Iota (ι) 1 Cancri

For those small telescope owners disappointed with our first offering, we present a beautiful copy of the famous double star Albireo [Beta (β) Cygni]. This is the fourth magnitude star Iota 1 Cancri, discovered in 1782 by William Herschel. It can be found by extending a line six degrees from Delta north through Gamma.

As mentioned in Close-Up above, steadily held binoculars are enough to resolve this pair. A three inch refractor at 45 power gives a perfect view, showing a yellow-orange star of 4.2 magnitude, 31 seconds from a vivid blue one of magnitude 6.6 — truly a stunning sight. Larger apertures tend to separate the pair too much, lessening the pleasing effect.

Among the colors given for this object by the classic observers are yellow and blue (Olcott), crocus and violet (Barns) and pale orange and clear blue (Smyth). Webb simply states "beautiful contrast" and points out that another fainter double lies in the southpreceding field (Struve 1266; 8, 9, and 24 seconds separation).

Iota (ι) 2 Cancri

An object often confused with Iota 1 is its close neighbor Iota 2, just three degrees to the northeast. Some star atlases fail to even label this star as Iota, designating it 57 Cancri.

More than a magnitude fainter than Iota 1, Iota 2 is nevertheless an interesting triple star system consisting of 6.3, 6.5 and 9.2 magnitude components having separations of 1.5 and 56 seconds, respectively.

Referring to the close pair, Webb calls this object a "Good test; elongated 3.7 inch (refractor), 80 (power); divided 144 (power)... both crocus yellow." He also passes along with the comment of Bird, one of his contemporaries, who called Iota 2 "one of the loveliest pairs." The close pair lies very new the Dawes limit for three and four inch apertures.

M-44

As discussed in Close-Up above, the center of Cancer is marked by a large open cluster of stars so loosely concentrated that it is more a binocular than a telescopic object. This is the well-known Beehive, M-44.

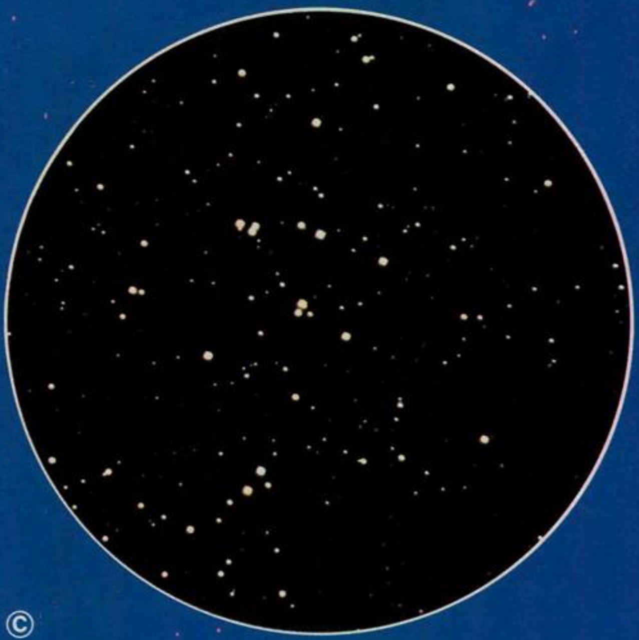
Most observers prefer the view in their finder to that in their main instrument because of this object's large size (95 minutes of arc). The blended light of several dozen faint stars greets the eye on a clear night; their combined intensities are that of a fourth magnitude star.

Galileo counted 36 stars in this cluster with his newly constructed telescope. In fact, the resolution of the nebulous Beehive was one of the first conquests of his instrument. We are told that the sight of these glittering stars filled him with delight and utter amazement.

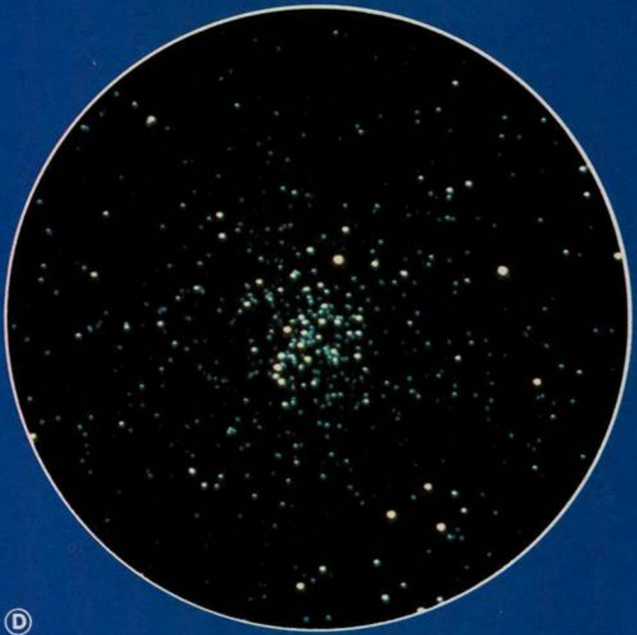
As with clusters in general, the number of member stars listed varies depending on the limiting magnitude given. Thus, M-44 contains about 80 stars down to 10th magnitude and perhaps as many as 400 to 18th magnitude. Counting individual stars in a rich cluster can be a frustrating experience, but with an object like the Beehive it can be fun. How many can you see with your telescope?

Despite its loose structure, M-44 does offer

M-44



M-67



A single star to the naked eye, Zeta Cancri can be separated into two stars with a small telescope, but at least a six inch instrument is necessary for further resolution. Diagram A shows Zeta as seen through a six inch Dynascope reflector at 200 power; one of the sixth magnitude components is revealed as a binary in itself. The field is 15 minutes of arc. In Diagram B, a three inch Edmund reflector at 60 power is used on the double star Iota 1 Cancri. The separation of the two members, shown here in a 1/2 degree field, is 31 seconds of arc. The contrasting colors are best seen through a telescope using low power. The large open cluster M-44 is shown in photograph C. Also known as Praesepe or the Beehive, this cluster is so loosely concentrated, and covers such a large area of the sky, that it is better seen through binoculars than a telescope — but even the unaided eye can detect M-44 as a hazy, fourth magnitude patch. The photograph, covering a field of about two degrees, is a 25 minute exposure taken through a home built, six inch f/5 Newtonian. Photograph D shows the smaller, fainter open cluster M-67. This group is much farther away than M-44, thus appearing more condensed. The 30 minute exposure, taken on GAF 200 film, was obtained through a six inch f/4.5 Newtonian reflector carried piggyback on a larger Newtonian. Opposite: Drawings by James Mullaney. Above: Photographs by Robert Provin.

much of interest to the telescopic observer. Barns, using his 10 inch reflector, noted "many doubles, triples, multiples, stars of varied hues." Webb tells us, "too large for usual fields but full of fine combinations. Two triangles will be noted." One of the pairs included in the cluster is the double Struve 1254, a duo of sixth and ninth magnitude white and orange stars 20 seconds apart. Together with several surrounding stars, this object forms a neat group within a group.

M-67

About eight degrees south of the Beehive is another of the few prominent open clusters visible in spring skies. This is M-67, easily picked up in a finder by sweeping two degrees directly west of fourth magnitude Alpha (α) Cancri.

This rich swarm of rather faint stars is easily resolved into its individual units with a four inch telescope at 45 power and is a fine sight in six inch and larger instruments at magnifications of 50 to 100 power.

Having an integrated magnitude of 6.1, the size of this object is generally given as about 15 minutes in diameter — but values twice that amount are reported by some observers. About 65 stars are packed into this area, giving M-67 a fairly concentrated appearance. Herschel counted over 200 stars in his large metal mirror reflectors.

Interestingly, Webb has little to say of this fine object, tersely stating "Cluster. Visible in finder." Barns, on the other hand, describes it as "Vivid, rich type of its exalted class." Olcott tells us that M-67 "is composed of stars of magnitudes 9 to 12.5 surrounded by brighter stars in the form of a semicircle. The cluster as a whole resembles a nebula in a small instrument."

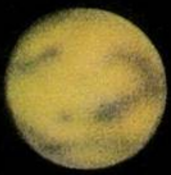
The semicircle is quite obvious in small apertures, becoming less apparent as telescope size increases. For best results with M-67, those infrequent nights of both good seeing and transparency (atmospheric clarity) should be watched for. This remote stellar commune lies nearly 3,000 light-years from us — six times the distance of M-44. This accounts for the fact that the Beehive has six times the angular size of M-67.

As we gaze from nearby objects like M-44 to distant ones such as M-67, the volume of space we are surveying — our sphere of inquiry — increases tremendously. This brings forcibly to mind something an unknown writer once penned: "The larger the sphere of our knowledge, the greater the contact of its surface with the infinity of our ignorance." Truly, we should approach the eyepiece with an open mind and humble heart.

Planet Finder

Ⓒ Ceres

March	1	15
R.A.	4h17m	4h33m
Dec.	+22°58'	+24°01'
Mag.	+7.5	+7.6



Ⓐ Mercury

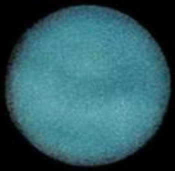
March	1
R.A.	21h21m
Dec.	-17°04'
Mag.	+0.0

Ⓑ Mercury

March	15
R.A.	22h52m
Dec.	-9°38'
Mag.	-0.6

Ⓜ Mars

March	1	15
R.A.	5h30m	5h55m
Dec.	+25°49'	+25°48'
Mag.	+0.6	+0.8



Ⓝ Neptune

March	15
R.A.	16h51m
Dec.	-20°57'
Mag.	+7.7

SUN

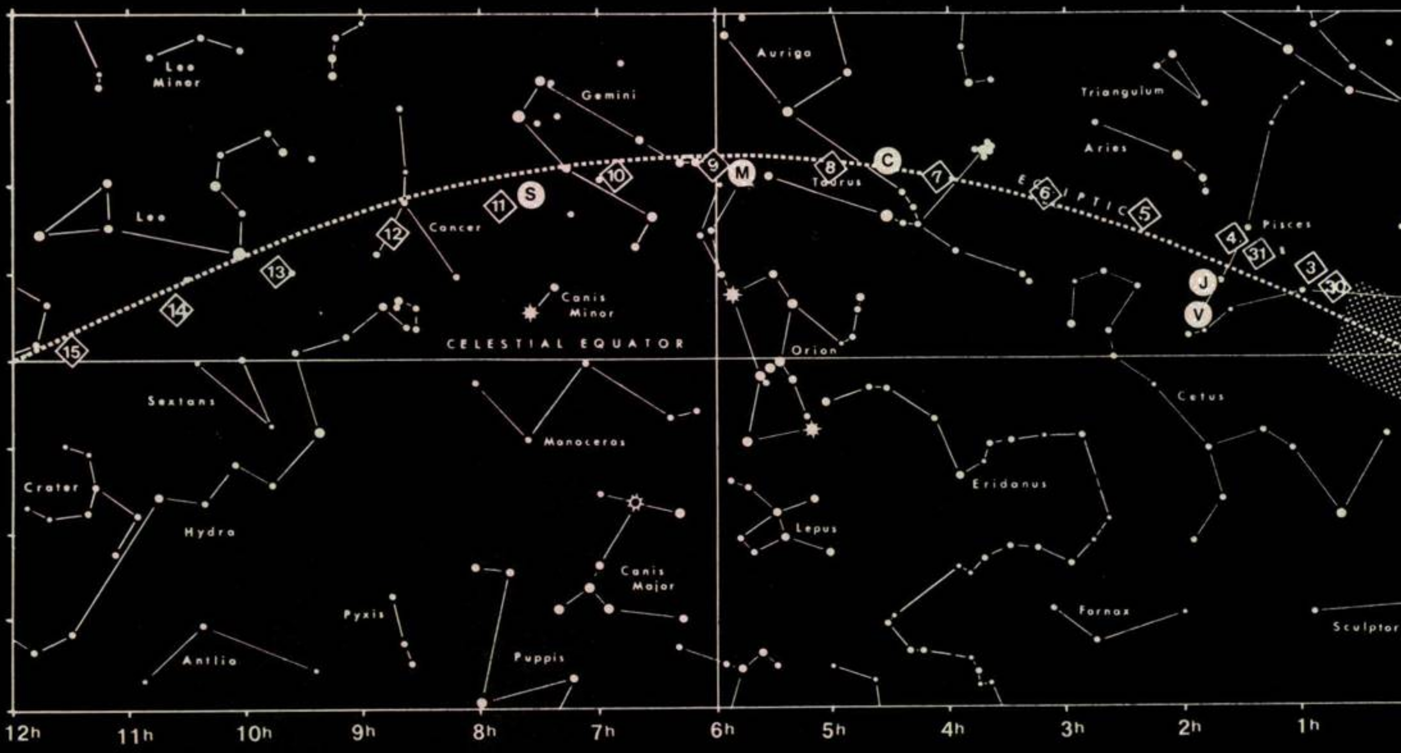
The sun is within the stippled zone throughout the month. Planets and stars near this area are not easily seen.

Ⓢ Saturn

March	1	15
R.A.	7h55m	7h53m
Dec.	+21°11'	+21°17'
Mag.	+0.1	+0.2

Ⓤ Uranus

March	15
R.A.	14h18m
Dec.	-13°15'
Mag.	+5.7


Leo Minor
Gemini
Auriga
Triangulum
Aries
Leo
Cancer
Taurus
ECLIPTIC
Pisces
Canis Minor
CELESTIAL EQUATOR
Orion
Sextans
Cetus
Monoceros
Crater
Eridanus
Hydra
Lepus
Canis Major
Pyxis
Fornax
Sculptor
Antlia
Puppis
S
M
C
J
V
15
14
13
12
11
10
9
8
7
6
5
4
31
3
30
12h
11h
10h
9h
8h
7h
6h
5h
4h
3h
2h
1h

The chart shows the positions of the moon, planets and brightest asteroids for the current month. Letters within the circles correspond to the letters beside each object in the data section above the map. Additional information about each object is given there. R.A. = right ascension and Dec . = declination, the two coordinates used to locate astronomical objects. The general coordinate system is indicated around the edge of the map. Mag . = magnitude, a

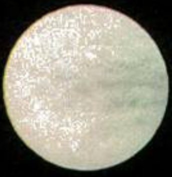
March 1976

Ⓥ **Vesta**

March	1	15
R.A.	1h27m	1h48m
Dec.	+3°31'	+5°57'
Mag.	+8.0	+8.2

Ⓙ **Jupiter**

March	1	15
R.A.	1h33m	1h44m
Dec.	+8°33'	+9°40'
Mag.	-1.7	-1.7



Ⓨ **Venus**

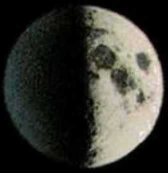
March	1
R.A.	21h06m
Dec.	-17°10'
Mag.	-3.4

Ⓩ **Venus**

March	15
R.A.	22h14m
Dec.	-12°03'
Mag.	-3.3

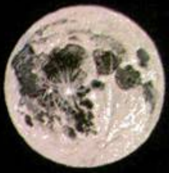
Ⓟ **Pluto**

March	15
R.A.	13h06m
Dec.	+11°55'
Mag.	+14



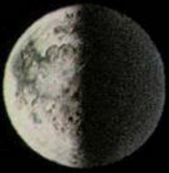
First Quarter

March 9



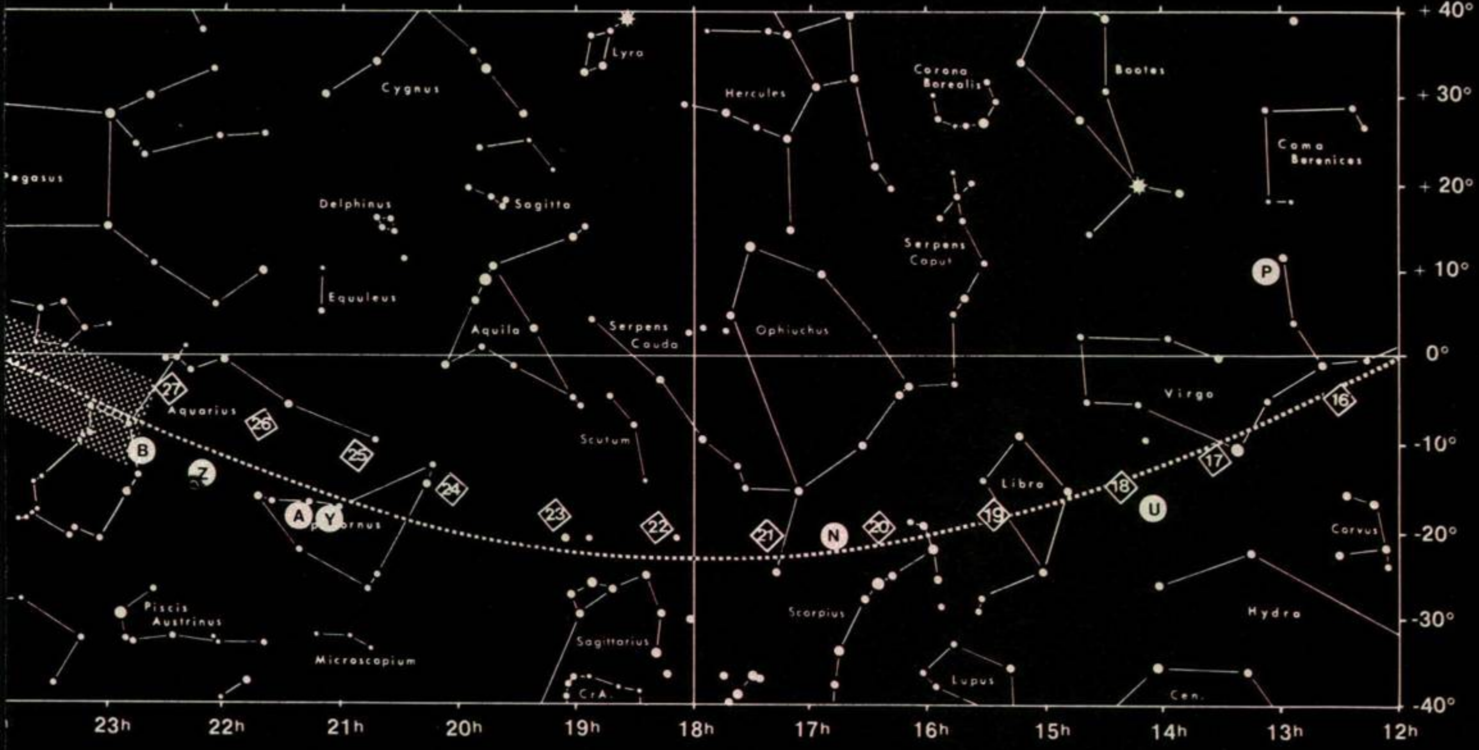
Full Moon

March 16



Last Quarter

March 22



+40°
+30°
+20°
+10°
0°
-10°
-20°
-30°
-40°
23h
22h
21h
20h
19h
18h
17h
16h
15h
14h
13h
12h
Pegasus
Cygnus
Lyra
Hercules
Corona Borealis
Bootes
Coma Berenices
Delphinus
Sagitta
Serpens Caput
Equuleus
Aquila
Serpens Cauda
Ophiuchus
Aquarius
Scutum
Virgo
Libra
Corvus
Capricornus
Piscis Austrinus
Microscopium
Sagittarius
CrA.
Scorpius
Lupus
Cen.
Hydra
P
B
Z
A
Y
N
U
27
26
25
24
23
22
21
20
19
18
17
16

measurement of the object's brightness. (The minus magnitudes indicate very bright planets.) The diamonds with numbers within them indicate the position of the moon for each day of the month; the numbers correspond to the dates. Positions of the planets are for the 15th of the month except for Mercury and Venus which are shown on both the 1st and 15th. Certain areas of this map and the Star Dome chart overlap each month.

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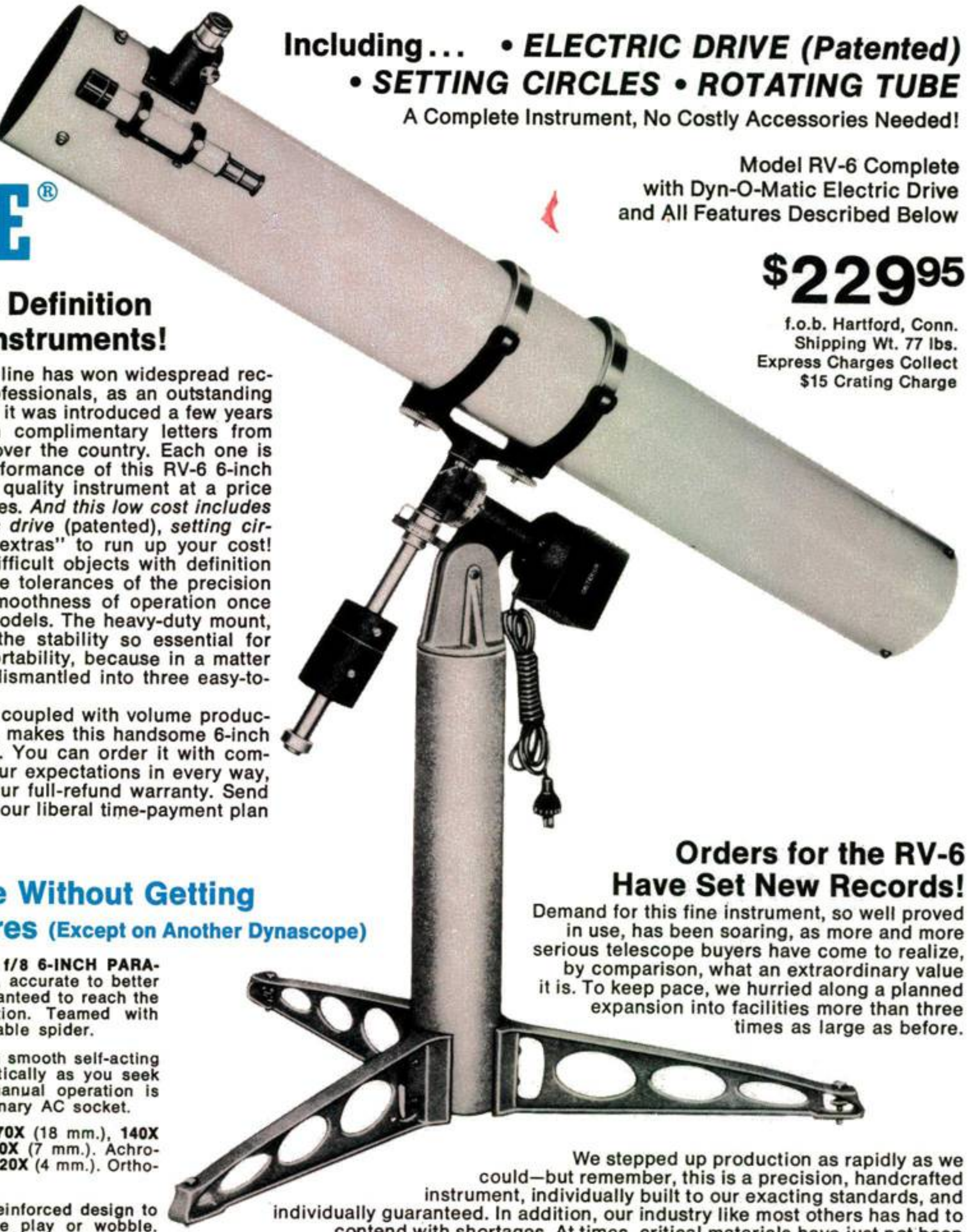

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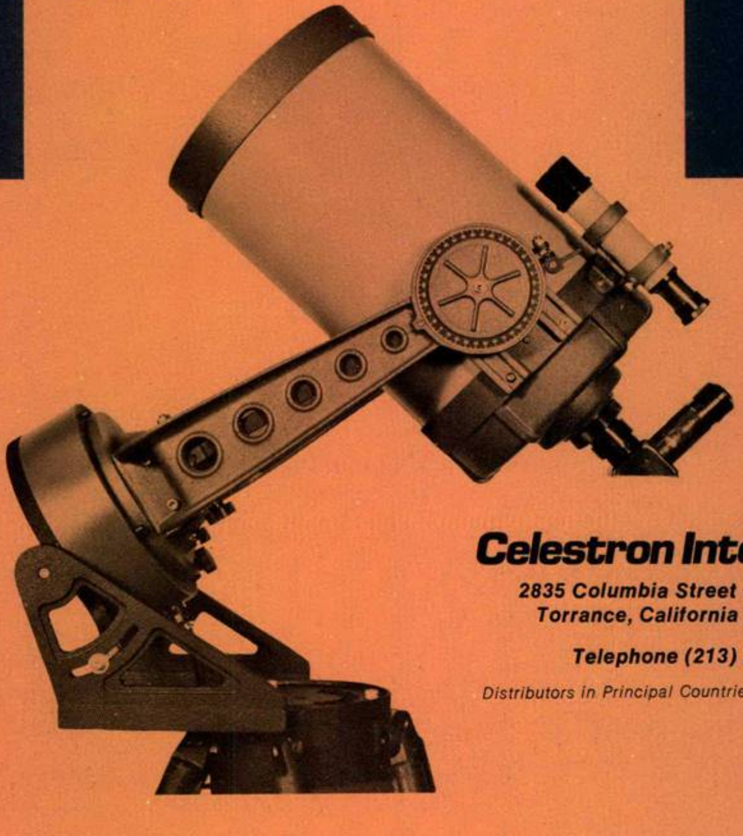

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